

**PESTICIDES IN SURFACE WATER FROM  
APPLICATIONS ON ORCHARDS AND ALFALFA  
DURING THE WINTER AND SPRING OF 1991-92**



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Staff Report of the  
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD  
CENTRAL VALLEY REGION

PESTICIDES IN SURFACE WATER FROM  
APPLICATIONS ON ORCHARDS AND ALFALFA  
DURING THE WINTER AND SPRING OF 1991-92

*February 1993*

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## FOREWORD

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## EXECUTIVE SUMMARY

The Central Valley Regional Water Quality Control Board's Basin Plan contains a narrative toxic objective stating that "all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in...aquatic life". In 1985 EPA published three species bioassay protocols that the Agency recommended for assessing compliance with state narrative toxic objectives. In 1991 the California State Water Resources Control Board adopted an Inland Surface Waters Plan stating that there shall be no chronic toxicity in receiving waters and that attainment of the objective shall be measured in freshwater by conducting the EPA three species bioassay test. Furthermore, the Plan directs Regional Boards to insure that follow-up studies are conducted in waters with consistent toxicity to determine the source of pollution and to insure that responsible parties take all reasonable steps to eliminate it.

Regional Board staff conducted periodic surveys of the San Joaquin watershed employing the EPA three species bioassay protocol from 1988 through mid 1990. The purpose of these surveys was to assess water quality in the Basin throughout several hydrologic cycles. A principal conclusion of the study was that there was a 43 mile reach of the San Joaquin River between the confluence of the Merced and Stanislaus Rivers that tested toxic to Ceriodaphnia, the invertebrate component of the EPA three species test, forty to fifty percent of the time. The primary cause of toxicity appeared to be pesticides entering the River in rain and tailwater runoff from row, field, and orchard crops.

Two agricultural practices that contribute to pesticide residues in the San Joaquin River in winter and early spring are the application of dormant sprays to orchards and the application of weevil control insecticides to alfalfa. The purpose of the present study was to provide additional information on orchard and alfalfa pesticide runoff in the Central Valley. The primary goal of the orchard portion of the study was to ascertain whether dormant spray runoff was restricted to the San Joaquin or was a general phenomenon and occurred in winter wherever there were orchards. The objective of the alfalfa portion of the study was to ascertain where the in situ sources were in the Estuary of alfalfa pesticides which had previously been measured there. A secondary objective of both portions of the study was to evaluate the importance of rain in controlling the movement of pesticide residues into surface water.

Eleven sites were monitored weekly from 13 January through 27 February 1992 for orchard runoff in the Sacramento and San Joaquin Basins. The sites represent two types of drainage basins. Six stations were located on water courses draining small watersheds (10,000 to 130,000 acres) with more than 10 percent of their acreage in orchards. The remaining samples were taken from three Central Valley Rivers (the Sacramento, Feather and Mokelumne) and from two locations in the southern Sacramento-San Joaquin Delta Estuary (Old River @ Cohen Road and the San Joaquin River @ Bowman Road). There was little precipitation in the watershed before 4 February. Five inches fell at Stockton and seven and a half at Marysville between 4 and 20 February .

Thirty percent of the samples taken during the orchard study were toxic<sup>1</sup>. Acute invertebrate mortality was observed on at least one occasion in water collected from each small drainage. Three sites were intermittently toxic during the dry period. Water from all locations tested toxic at least once during the storm. Much less toxicity was observed in water collected from Rivers. Only water from the Mokelumne tested toxic during the dry period (27 January and 3 February, 1992). In contrast, water collected during the storm from the Feather, Old and San Joaquin Rivers was toxic. Only the San Joaquin River at Bowman remained toxic after the storm.

All water samples which tested toxic (25 samples) were submitted for pesticide analysis. Six pesticides were detected: diazinon, diuron, methidathion, bromocil, protham and fluometuron. Diazinon, diuron, and methidathion were the most common compounds observed. These pesticides were present in 90, 88, and 38 percent of all samples analyzed at average concentrations of 0.87, 4.72, and 0.41 ppb, respectively. Except in three cases, diazinon and methidathion concentrations appeared sufficiently elevated to explain part or all of the bioassay mortality.

The Department of Pesticide Regulation, Fish and Game, and the U.S. Geological Survey also had ongoing monitoring programs and collected some pesticide and/or bioassay data in the Estuary during the storm. The data suggest that the San Joaquin River transported acutely toxic water into the Estuary for at least an eight day period, 12 through 19 February, 1992. The toxicity may have reached as far north on the San Joaquin River as Empire Tract and Venice Island before encountering Mokelumne and Sacramento River flow. Water from these sources should have diluted the pesticides and reduced or eliminated invertebrate toxicity. The conclusion that pesticides from the San Joaquin River caused acute toxicity in the Estuary is supported by bioassay and pesticide data collected on 17 February by the Regional Board on the Old River @ Cohen Road and on the San Joaquin River @ Bowman Road. Both samples produced 100 percent invertebrate mortality in 48 hours and had diazinon concentrations between 0.47 and 0.67 ppb.

Thirteen sites were monitored weekly in a crescent around the periphery of the Sacramento-San Joaquin Delta Estuary from 9 March to 27 April 1992 as part of the alfalfa study. As in the orchard portion of the study, the sites were a mix of stations draining small and large basins. Seven drained small watersheds. Four of these were drains on Delta Islands and Tracts while three were small water courses draining agricultural areas on the mainland adjacent to the Estuary. Six sites were located on large Delta waterways.

The spring of 1992 was unusually dry and the alfalfa study is thought to predominately represent water quality during a dry period. Less toxicity was observed in the alfalfa than in the orchard portion of the study. Thirteen percent of the samples collected for the alfalfa study were classified as toxic. Toxicity was observed in only two small watersheds, Ulati Creek and Bishop Tract Main drain. Ulati Creek tested toxic on three occasions while Bishop Tract Main Drain was toxic twice. Only sporadic toxicity was observed in waterways in the

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<sup>1</sup>A water sample was classified as toxic if test organism mortality was 30 percent greater than in the associated laboratory control.

Estuary. Eight samples tested toxic. Water from Paradise Cut was toxic half of the time (9 and 16 March and 13 and 20 April). Toxicity was only measured once in four of the other six waterways.

Eleven toxic samples were submitted for pesticide analysis. Diuron, diazinon, chlorpyrifos, and carbofuran were detected in the toxic samples. Much less success was achieved in explaining the bioassay results in the alfalfa study than in the orchard study. Only the diazinon concentration (0.24 ppb) measured in Ulati Creek on 6 April and the carbofuran concentration measured in Ulati Creek (1.0 ppb) on 23 March and in Bishop Cut (1.9 ppb) on 13 April were thought high enough to explain part or all of the bioassay results. These chemicals may have originated from applications on alfalfa.

Also included is a discussion of the likely mechanisms responsible for off-target orchard pesticide movement. These include drift during application, storm runoff from treated orchards and atmospheric contamination of rainwater. Dormant sprays have routinely been detected in composite rain samples from storms in the Fresno area. Samples from two precipitation events (0.53 and 0.34 inch storms) contained diazinon at acutely toxic concentrations to Ceriodaphnia.

## INTRODUCTION

The Central Valley Regional Water Quality Control Board's Basin Plan contains a narrative toxic objective stating that "all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in ... aquatic life". In 1985 EPA published three species bioassay protocols (EPA 1985a) that the Agency recommended for assessing compliance with state narrative toxic objectives (54 CFR 23868). In 1991 the California State Water Resources Control Board adopted an Inland Surface Waters Plan stating that there shall be no chronic toxicity in surface water<sup>2</sup> and that attainment of the objective shall be measured in freshwater by conducting the EPA three species bioassay test. Furthermore, the Plan directs Regional Boards to insure that follow-up studies are conducted in waters with consistent toxicity to determine the source of pollution and to insure that responsible parties take all reasonable steps to eliminate it.

Regional Board staff conducted periodic surveys of the San Joaquin Basin employing the EPA three species bioassay protocol from 1988 through mid-1990. The purpose of these surveys was to assess water quality in the watershed throughout several hydrologic cycles. A principal conclusion of the study was that there was a 43 mile reach of the San Joaquin River between the confluence of the Merced and Stanislaus Rivers which tested toxic to Ceriodaphnia dubia, the invertebrate component of the EPA three species test, forty to fifty percent of the time (Foe and Connor, 1991). The primary cause of toxicity appeared to be pesticides entering the River in rain and tailwater runoff from field, row and orchard crops.

Two agricultural practices which contribute to pesticide residues in the San Joaquin River in winter and early spring are the application of dormant sprays to orchards and the application of weevil control insecticides to alfalfa. Evidence for the presence of these residues comes from studies conducted by the Regional Water Quality Control Board, the U.S. Geological Survey, and the California Department of Pesticide Regulation. In February, 1990, the Regional Board repeatedly measured Ceriodaphnia toxicity in water samples collected from the Merced and San Joaquin Rivers (Foe, 1990a). All samples contained diazinon and parathion at concentrations capable of causing the observed invertebrate response. In one survey, 35 miles of San Joaquin River exceeded the recommended freshwater criteria to protect aquatic life for diazinon (National Academy of Sciences) and parathion (U.S. EPA) by 10 to 20 fold. The major seasonal use of these two insecticides in the Basin is as dormant sprays on apricot, peach and almond orchards. In April of the same year, diazinon and carbofuran were measured in water samples collected from the San Joaquin River which tested toxic to Ceriodaphnia (Foe, 1990b). Insecticide levels were sufficiently elevated to explain part or all of the invertebrate toxicity. On 23 April, 1990, thirty six miles of River exceeded the recommended diazinon criteria by 80 to 170 fold. The principal use in March and April of diazinon is to control weevils and aphids on alfalfa.

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<sup>2</sup>Surface freshwaters include lakes, rivers, creeks and major agricultural drains.

In January, 1991, the U.S. Geological Survey began daily monitoring for pesticides in the San Joaquin River at Airport Way and in the Sacramento River at the City of Sacramento (Crepeau et al., 1991). The sites establish the legal boundaries on the two Rivers where the Sacramento-San Joaquin Delta Estuary begins. A well defined diazinon concentration maxima and traces of parathion were detected at Airport Way in February 1991. The authors attribute these concentrations to the off-site movement of pesticides previously applied to almond orchards. In early March of the same year, carbofuran was detected at Airport Way concurrently with a second increase in diazinon and with traces of chlorpyrifos. The ~~second~~ suite of insecticides were believed to result from applications on alfalfa in February and March. During both time periods, the highest concentrations of pesticides in the River appeared to be associated with precipitation (personal communication, Kathy Kuivila). In the spring of 1991, the Survey also conducted a study to assess the concentration and distribution of alfalfa pesticides in the Sacramento-San Joaquin Delta Estuary (Kuivila et al., 1992). Carbofuran, but not diazinon, increased westward in the Estuary to Chipps Island. The increase in carbofuran was attributed to inputs from local unmeasured sources within the Delta while the decrease in diazinon was thought to result from the mixing of River and uncontaminated seawater.

The California Department of Pesticide Regulation collected water samples twice weekly between 4 March and 25 April, 1991, and between 23 December and 27 February, 1992, from the San Joaquin River at Laird Park for pesticide analysis. In addition, the Department completed four Lagrangian surveys during this time period. Lagrangian surveys consist of sampling a parcel of water moving down River and all the major tributary inputs prior to their mixing with the river water parcel to determine how River pesticide concentrations change with downstream distance. The Department has released the pesticide analytical results but has not yet interpreted the data (Ross, 1991; 1992). The Department measured diazinon, methidathion, parathion, chlorpyrifos, carbofuran, carbaryl and endosulfan in samples collected between December and February and diazinon, parathion, chlorpyrifos, malathion, carbofuran, oxamyl and endosulfan in samples collected during March and April. Other Department records (Department of Pesticide Regulation, 1990a) indicate that the primary use of diazinon, parathion, methidathion, chlorpyrifos, and malathion in the watershed in January and February is on orchards. In March and April, diazinon, chlorpyrifos, methidathion, and carbofuran are extensively used on alfalfa. As in the U.S. Geological Survey studies, the highest pesticide concentrations in the River seem to be associated with rainfall.

The purpose of the present study was to provide additional information on orchard and alfalfa pesticide runoff in the Central Valley. Apricots, peaches and almonds are the three most common types of deciduous orchard in the portion of the Central Valley which the Regional Board, the U.S. Geological Survey and the Department of Pesticide Regulation monitored for surface water pesticide residue. However, dormant sprays are recommended for use on all California stonefruit<sup>3</sup> (Chemical and Pharmaceutical Press, 1990). There are slightly less than 900,000 acres of stonefruit in the Central Valley (Department of Commerce, 1987) and

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<sup>3</sup>Peach, nectarine, plum, prune, apple, pear, almond, apricot and cherries.

1,100,000 pounds of dormant spray active ingredients were applied on them in the spring of 1990 (Department of Pesticide Regulation, 1990a). The primary goal of the orchard portion of this study was to ascertain whether dormant spray runoff was restricted to the San Joaquin or was a general phenomenon that occurred in winter wherever stonefruits are grown. The objective of the alfalfa portion of the study was to ascertain the in situ sources of carbofuran which resulted in insecticide concentrations increasing westward in the Estuary in the U.S. Geological Survey studies (Kuivila et al., 1992). A secondary objective of both portions of the study was to evaluate better the importance of rain in controlling the movement of pesticide residue into surface water.

## METHODS AND MATERIALS

### Bioassay and water collection procedures

The invertebrate component, Ceriodaphnia dubia<sup>4</sup>, of the EPA three species test was employed to ascertain whether dissolved pesticides were present at concentrations causing mortality within four to seven days. Water samples were collected as one time subsurface grabs in amber glass containers<sup>5</sup> and held in the laboratory at <4.0°C until use. All bioassays were started within 24 hours of water collection. All tests, except the last two surveys, were conducted at Dr. David Hinton's laboratory at U.C. Davis employing procedures described in EPA (1989a). Tests of water collected on the last two surveys (20 and 27 April) were conducted at Dr. Allen Knight's laboratory at U.C. Davis. Briefly, tests were conducted under controlled temperature and photoperiod. Dissolved oxygen, electrical conductivity, and pH were measured at the beginning and end of the test to insure that all parameters were within limits known not to cause mortality. In addition, the same parameters were measured in all samples on days when 50 percent or greater mortality was observed. Dissolved oxygen, electrical conductivity and pH were measured with calibrated YSI model 57 and 58, YSI model 33, and a VWR model 59 meter, respectively. Ammonia was only measured in water samples determined to be toxic. Ammonia concentration was measured with a Hach kit (NI-8) using the Nessler reagent method. Water quality data are summarized by survey date in Appendix A and appeared in all instances to be within acceptable limits to support aquatic life. Test water was renewed daily whereupon animals were fed a diet of unfermented trout chow and the green alga Selenastrum as specified in Hinton, et al., (in prep). This is a different diet than is recommended in EPA (1989a). Sierra Spring Water was used as the laboratory control water after amending it with salts to a moderately hard standard (EPA, 1985b). Bioassay organisms were obtained from in-house cultures and were less than 24 hours old at the start of the test.

### Bioassay test acceptability and definition of toxicity.

EPA (1989a, 1991) recommends that Ceriodaphnia bioassay results be considered acceptable if control survival is at least 90 percent in four day tests and 80 percent in seven day tests. Control survival on all survey dates met these criteria.

A water sample was classified as toxic in both the four and seven day tests if test organism mortality was 30 percent greater than in the associated laboratory control.

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<sup>4</sup>Ceriodaphnia appears to be the most sensitive of the EPA three species to insecticides.

<sup>5</sup>200 series I-Chem sampling bottle

### Pesticide analysis

Additional water was collected concurrently in cubitainers<sup>6</sup> from all sites and stored in the dark at <4.0°C. If the *Ceriodaphnia* bioassay results suggested the presence of pollutants, then samples were sent to Eureka Laboratory<sup>7</sup> during the orchard portion of the study for organophosphate and carbamate pesticide analysis. These analyses were conducted by EPA 622 and 632 methods, respectively. During the alfalfa portion of the study, the samples were sent to either Eureka or the U.S. Geological Survey for analysis. Pesticide analysis at the Survey was conducted by methods outlined in Wershaw *et al.* (1987). Additionally, several samples were split three ways and analyzed for organophosphate pesticides by Eureka Laboratory, the California Department of Pesticide Regulation's Sacramento Laboratory and the U.S. Geological Survey's Central Laboratory at Denver, Colorado. Finally, five non-toxic water samples (15 percent of the total) also were submitted for analysis. These samples were selected for testing because they were collected from sites where pesticide contamination was suspected but no toxicity measured. A more extensive data base of pesticide residues in randomly selected non-toxic water samples is available from a second San Joaquin pesticide study (Foe, in prep).

### Sampling Locations--Orchard Study

Water samples were collected from eleven sites in the Sacramento and San Joaquin Basins (Figure 1). Sampling locations are summarized in Appendix B. The sites represent two types of drainage basin. First, six stations were located on watercourses draining small watersheds (10,000 to 130,000 acres) with 10 to 70 percent of their acreage in orchards. Results from these locations are thought to be representative of the water quality of similar sized basins with orchards in the Central Valley. Second, samples were taken from three Central Valley Rivers (the Sacramento, Feather and Mokelumne) and from two locations in the southern Sacramento-San Joaquin Delta Estuary (the Old River @ Cohen Road and the San Joaquin River @ Bowman). River and Delta sites were sampled to increase our understanding of the connection between the occurrence of pesticides in creeks and their presence in rivers and the Estuary.

Orchard land use is estimated for the six small basins in Table 1. Unfortunately, no watershed was found with pure stands of any one kind of tree. Therefore, it is impossible from this study to ascertain the relative pesticide contribution from any one type of orchard. The basins chosen for monitoring are thought to represent typical orchard mixtures. Almonds and walnuts were well represented at most sites. They are also the most common orchard types in the Valley. In contrast, pears, peaches/nectarines and cherries are sparsely represented and they are less common in the Central Valley. No watershed with apples was monitored. Some apples are grown in El Dorado, Stanislaus, San Joaquin and Kern Counties; however, most apples are grown outside the Central Valley.

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<sup>6</sup>200 series I-Chem polyethylene cubitainers.

<sup>7</sup>Eureka Laboratory, Inc., 6790 Florin Perkins Rd., Sacramento, Cal.



## Alfalfa Study

Thirteen sites were located in a crescent around the periphery of the Sacramento-San Joaquin Delta Estuary (Figure 2). The location of the sites is described in Appendix D. The purpose of the sampling design was to obtain pesticide runoff data from all the main alfalfa growing areas in and around the Estuary. As in the orchard portion of the study, the sites are a mix of stations draining small and large basins. Seven drain small basins. Four of these were main drains on Delta Islands and Tracts--Bishop Tract (Site 11), Sutter Island (Site 13), Fabian Tract (Site 10) and Elkhorn Slough on Ryer Island (Site 12). Bishop Tract was planted almost exclusively in alfalfa while the other three were a mixture of alfalfa, grain, and fallow land. Three small watercourses, Ulati Creek, Tom Paine Slough and Paradise Cut, drain agricultural areas on the mainland adjacent to the Estuary. Ulati Creek (Site 8) receives runoff from agricultural areas in Yolo and Solano Counties. Major crops in Solano and Yolo Counties are orchards, grain, alfalfa, sugarbeets and fallow land. The Vacaville Sewage Treatment Plant discharges into Alamo Creek which is tributary to Ulati Creek. Finally, Tom Paine Slough (Site 9) and Paradise Cut (Site 2) receive discharge from northwest San Joaquin County. Much of this portion of the County is planted in alfalfa. Both of the latter waterways are in the tidal prism and receive dilution from Old River.

Six sites were located on large Delta waterways. All are within the tidal prism. A potential problem with tidally influenced samples is that water dynamics in the Estuary is complicated and the origin of any water parcel is never known with certainty. Three sites were located on the northern side of the Estuary. Steamboat Slough (Site 7) was sampled to assess the water quality of the Sacramento River shortly after entering the Estuary. Water samples from Cache Slough @ Liberty Island Rd (Site 5) and from Cache Slough @ Ryer Island (Site 6) measure water quality of a mixture of drainage from Cache, Lindsey, Prospect Sloughs and the Sacramento River. The remaining three sites were located in the eastern and southern Delta. Water samples from Bishop Cut (Site 4) provide an assessment of water quality in a back channel on the eastern periphery of the Delta. This water is most probably a mix of Sacramento, Mokelumne and local island drainage. Finally, the Old River at Tracy Rd (Site 1) and the Delta Mendota Canal at Byron Road (Site 3) were sampled to provide an indication of water quality in well flushed channels in the southern Delta. Most of the Old River and Delta Mendota Canal water is a mixture of Sacramento and San Joaquin River water and drainage from southern Delta islands.

## RESULTS AND DISCUSSION

Orchard and alfalfa results are presented separately below. Each includes information on rainfall patterns, bioassay and pesticide analytical results and the ecological significance of the data. Also included is a section summarizing the recommended criteria to protect aquatic life for all the pesticides detected in this study.

ORCHARD STUDY--Rainfall Pattern Precipitation patterns are presented in Figure 3 for two locations in the study area. In general, the rainfall totals are greater in the northern Valley (Marysville) than in the Delta (Stockton). However, the general precipitation pattern is similar at both locations. The first rain storm of the calendar year occurred about a week prior to the start of the study. Only trace amounts of precipitation fell during the remainder of January and early February. Four surveys were conducted during this time period. These data are thought to represent water quality during a dry/light precipitation winter period. No flow data are available for the six small drainage basins monitored. However, slight to small flows were observed consistently during the dry period at all locations except Clark's Ditch which was dry. French Camp Slough receives runoff from the South San Joaquin Irrigation District Canal, Little Johns Creek and Lone Tree Creek. The latter two always had some flow. In addition, the French Camp Slough site is within the tidal prism and has a strong daily tidal exchange.

A series of major storms occurred between 4 and 20 February (Figure 3). About three quarters of an inch of rain fell in Stockton in the four days preceeding the 10 February sampling event and another four inches fell in the week prior to the 17 February survey. About seven and a half inches of rain fell in the same two week period at Marysville. All creeks and sloughs rose steadily during the two week period; Lone Tree Creek was near flood stage on 17 February. Significant increases also were observed in the flows of the San Joaquin and Sacramento Rivers (Figure 4). Both carried the largest flow observed during the water year. Only a limited amount of water quality data exist for either small drainages or Valley rivers during large winter storms. The information collected during the 10 through 17 February storm event is important as it provides an indication of surface water quality in the Central Valley and associated portions of the Estuary during this critical time period.

Flows in all water bodies dropped after the February storm and were, by the last sampling period (24 February), close to those observed prior to the storm.

### Toxicity

Bioassay results are summarized in Table 2. Acute<sup>a</sup> invertebrate toxicity was observed on at least one occasion in water samples collected from each small drainage basin (Table 2). Three sites (French Camp Slough, Gilsizer Slough, and Lone Tree Creek) were intermittently toxic during the four weeks of dry weather. Marsh and Ledgewood Creeks were never toxic. In contrast, water samples collected from all small basins during the two week storm were toxic either

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<sup>a</sup>Thirty percent or greater mortality in 96 hours.

during one or both sampling periods. All these storm water samples produced 100 percent mortality within four days, most within one day (Table 3). Only Clark's Ditch and Gilsizer Slough remained toxic a week after the February storm.

Much less toxicity was observed in water collected from rivers. Only water from the Mokelumne River tested toxic during the dry period (27 January and 3 February, 1992; Table 2). In contrast, water collected during the storm from the Feather, Old and San Joaquin Rivers was toxic. Feather River samples collected at the beginning of the storm (10 February) produced 50 percent mortality in seven days whereas the Old River and San Joaquin River were toxic on the second date (17 February). The latter two samples produced 100 percent mortality within one day (Table 3). No toxicity was observed during the storm in samples collected from the Mokelumne or Sacramento River.

Concurrent bioassay testing on water collected in another Regional Board study in the San Joaquin Basin demonstrated no invertebrate mortality (within seven days) in samples collected at the beginning of the storm (10 February) from the Stanislaus, Tuolumne, Merced or San Joaquin Rivers (Foe, in prep). However, samples collected on 17 February from the Merced, Tuolumne and San Joaquin River at Airport Way were toxic. The Merced and San Joaquin River samples produced 100 percent mortality in two days whereas the Tuolumne River sample took six days to do so.

Only the San Joaquin River at Bowman remained toxic a week after the storm. No toxicity was seen on the same date in water samples collected from the Merced, Tuolumne, Stanislaus or San Joaquin River south of Airport Way (Foe, in prep).

#### Pesticide Analysis

Water samples were collected from each site for organophosphate and carbamate pesticide analysis. Twenty nine samples were submitted for analysis. Twenty-five of these were classified as toxic while four were not. Six pesticides were detected: diazinon, diuron, methidathion, bromocil, protham and fluometuron (Table 3). Diazinon, diuron, and methidathion were the most common pesticides observed. These compounds were present in 90, 88, and 38 percent of toxic and nontoxic samples at average concentrations of 0.87, 4.72, and 0.41 ppb, respectively.

Pesticide concentrations in toxic water samples appeared to increase during the storm (Table 4). This is surprising as none of the storm water samples are thought to represent a first flush type phenomenon. This suggests that pesticide loading to rivers and the Estuary from small water courses may increase during large storms. The only other data set which is available for a similar analysis is one collected by the Department of Pesticide Regulation. This data also tends to support an increase in pesticide loading during winter storms. The Department conducted two surveys of pesticide concentrations in eight creeks and agricultural drains in the San Joaquin Basin (Ross, 1992). One survey was carried out before (27-31 January) and the other toward the end of the February storm (17-19 February). Mean diazinon concentrations in small water courses were 0.1 and 0.4 ppb, respectively.

Diazinon, methidathion and diuron were also present in toxic samples collected during the storm from the Feather River and from the Estuary at the Old and San Joaquin River sites (Table 3). This finding confirms that the pesticides measured in small water courses in this and the Department of Pesticide Regulation study are finding their way into rivers and the Estuary. Further evidence that this is a valley-wide phenomenon is that diazinon was also measured on 17 February at concentrations between 0.28 and 0.35 ppb in samples taken from the Merced, Tuolumne and San Joaquin River at Airport Way (Foe, in prep). These values represent some of the highest diazinon concentrations measured in these systems during the year. No chemical analysis for methidathion or diuron was attempted in the second study so no information is available about the distribution of these chemicals.

Three water samples which tested toxic (French Camp Slough on 10 February and the San Joaquin and Old Rivers on 17 February) were split between Eureka, Department of Pesticide Regulation and the U.S. Geological Survey for organophosphate pesticide analysis. The resulting QA/QC data (Table 3) is somewhat confusing as each laboratory had some different compounds in their analytical scans and the Survey had a lower reporting limit (0.01 ppb) than did the Department of Pesticide Regulation and Eureka Laboratory (0.05 ppb). However, all three laboratories agree that diazinon was present in the three samples. In addition, Eureka and the Department of Pesticide Regulation measured methidathion in two of the splits. Methidathion is not part of the U.S. Geological Survey's organophosphate pesticide scan. There was poor agreement, however, among the three laboratories on the precise amount of pesticide residue present in any one sample<sup>9</sup>.

#### Cause of invertebrate toxicity

Only a limited amount of Ceriodaphnia toxicity information exists for the insecticides detected in this study. The acute toxicity of diazinon to Ceriodaphnia does not appear to be a strong function of the duration of exposure (Table 5). The 24 to 96 hour  $LC_{50}$  concentration is between 0.4 and 0.6 ppb. The seven day incipient concentration producing a 25 percent decrease in reproduction is 0.12 ppb. Less is known about the toxicity of methidathion and diuron. Ongoing work by the California Department of Fish and Game suggests that the 96 hour  $LC_{50}$  concentration for methidathion is between 2.0 and 2.4 ppb. Diuron is much less toxic. The 96 hour  $LC_{50}$  concentration is about 12,000 ppb.

No information exists on the additive toxicity of these pesticides. However, chemicals which act on the same physiological system are usually found to exhibit an additive type of toxicity. This report assumes additive toxicity for co-occurring orchard insecticides as the mode of action of each is to inhibit the acetylcholinesterase enzyme system.

Table 3 lists, based upon the information in Table 5 and the authors judgement, whether the measured pesticide concentrations could explain the observed bioassay

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<sup>9</sup>For example, for diazinon the maximum percent difference in concentration between the three laboratories on the three occasions was 48, 88 and 68 percent.

response. The analysis is important as unexplained toxicity is an indication of the presence of other unidentified pollutants. Of course, the presence of a pesticide in a sample at concentrations which can explain Ceriodaphnia toxicity does not necessarily mean that other unidentified compounds might not also have been present and have contributed to the response. About half of the time (11 instances), methidation and diazinon appear sufficiently elevated to explain the toxicity. On another eleven occasions, the observed pesticide concentrations can explain part, but not all, of the impairment. Finally, there appears to be insufficient pesticide residue present in three samples to explain any of the invertebrate response. Follow-up studies need to be initiated to identify the additional toxic compounds.

Three groups of chemicals may account for some unexplained toxicity. First, five insecticides are extensively used as dormant sprays in California (Table 6). Only two of these, diazinon and methidathion, were detected routinely in this study. However, the other three (parathion, chlorpyrifos, and malathion) have regularly been observed in orchard runoff at concentrations below Eureka's reporting limit in the other San Joaquin Basin pesticide study (Foe, in prep). In the present work, the U.S. Geological Survey measured trace amounts of one or more of these insecticides in three of eight samples analyzed (Table 3). This suggests that these compounds may also have been present at concentrations below the Eureka reporting limit in other samples not analyzed by the Survey. Two elements are of toxicological concern. First, chlorpyrifos is acutely toxic to Ceriodaphnia (96 hour  $LC_{50}$  = 0.08 to 0.1 ppb, Table 5) at concentrations near Eureka's reporting limit (0.05 ppb). Second, some invertebrate toxicity may be caused by the additive toxicity of co-occurring insecticides at concentrations below the Eureka reporting limit.

A second set of chemicals that may account for some Ceriodaphnia toxicity are degradation products. Eureka Laboratory did not analyze for any dormant spray degradation products. However, the Department of Pesticide Regulation did and measured diazinon-oxon, a degradation product of diazinon, in one of three split samples (French Camp Slough on 10 February 1992; Table 3). No information was found in the literature on the toxicity of any dormant spray degradation products. However, it is known that some organophosphate pesticides, like diazinon and chlorpyrifos, are not potent acetylcholinesterase inhibitors and must be converted to their oxygen analogues (oxons) before poisoning can occur (reviewed in Sheipline, in prep). For example, diazinon-oxon is about 10,000 times more effective in reducing enzyme activity than diazinon. It seems possible, therefore, that some dormant spray degradation products may be as or more toxic than their parent compounds and may have been present in some of the samples at concentrations contributing to Ceriodaphnia toxicity. More information needs to be obtained on the toxicity and distribution of common insecticide degradation products in surface water in California.

Finally, three sites, Gilsizer Slough, Marsh Creek and French Camp Slough, also drain urban areas (Table 1) and may have carried urban runoff, particularly during the storm. Both wet and dry weather urban runoff is known to be toxic to Ceriodaphnia (Foe, 1987; Cook and Lee, 1992; Lee and Cook, 1992). The National Urban Runoff Program routinely identified copper, lead and zinc in urban sumps at concentrations exceeding EPA acute criteria to protect freshwater aquatic life (EPA, 1983). A limited amount of Toxicity Identification Evaluation work (TIE;

EPA 1988, 1989b,c) has been conducted on urban runoff. Several wet weather urban runoff TIEs have implicated heavy metals (including copper, zinc and lead) and unidentified organic compound(s) (Lee and Cook, 1992; Cook and Lee, 1992). To our knowledge, no dry weather urban runoff Ceriodaphnia TIE work has yet been conducted.

On four occasions non-toxic water samples were submitted for pesticide analysis (the Old and San Joaquin Rivers on 3 February and the Feather and Mokelumne Rivers on 17 February; Table 3). All samples were analyzed by the U.S. Geological Survey to insure the lowest possible detection limit. No insecticides were measured in these samples at concentrations thought likely to cause invertebrate toxicity.

### Ecological Significance

There are about 900,000 acres of deciduous orchards in California (Table 7). About 96 percent of these are located within the Central Valley<sup>10</sup>. Off-target movement of dormant sprays into surface water is likely, therefore, to occur mostly in the Central Valley<sup>11</sup>.

Orchards are grown along the entire Valley floor. Twenty counties have more than 5,000 acres of fruit and nut trees. Five counties, San Joaquin, Stanislaus, Merced, Fresno, and Kern, have more than 75,000 acres of trees (Table 7). In the Sacramento Valley, orchards tend to be distributed in a narrow lens along the Sacramento and Feather Rivers. Few orchards occur, with the exception of pears, in the Delta. In the San Joaquin and Tulare Basins, orchards are widely dispersed over the entire Valley floor. Current and previous work suggest that dormant sprays pose water quality problems in both the Sacramento and San Joaquin Basins (Foe, 1990a; Foe in prep). Work still needs to be done to ascertain whether similar problems occur in the Tulare Basin.

It is not known how many constructed agricultural drains, creeks and sloughs in the Valley are presently being impacted in the winter by dormant sprays. Acute Ceriodaphnia toxicity was observed in January and February in this and the other San Joaquin pesticide study in every watershed tested with orchards (Foe, in prep). In this study, diazinon and methidathion concentrations were sufficiently elevated to explain completely about half of all the incidents of toxicity. Furthermore, sprays appear to have contributed to the toxicity observed in all but three of the remaining samples. Little data are available on the toxicity of dormant sprays to other aquatic forms. However, some other freshwater insect, copepod, and cladoceran species appear to be about as sensitive as Ceriodaphnia is to diazinon and other dormant sprays (Foe, 1992; Sheipline, in prep). These small organisms are important components of aquatic ecosystems because they are

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<sup>10</sup>Orchards constitute about 5 percent of all agricultural land under cultivation in the Valley.

<sup>11</sup>A discussion is presented in Appendix C of why it is believed that orchards are the primary source of the diazinon and methidathion measured in this study. Also included is a discussion of the mostly likely mechanisms responsible for transporting the chemicals off-site.

the principal food of many types of larval and juvenile fish. As of yet, it is not known what the impact of dormant sprays are on the ecology of small water courses in the Central Valley during winter and early spring. This merits investigation.

Toxicity associated with dormant sprays was also measured in the Sacramento-San Joaquin Delta Estuary during the February storm. An accurate assessment of the ecological impact on the Estuary of this pulse of contaminants is beyond the scope of this report. However, any assessment must involve estimates of the magnitude, duration, and frequency of such toxic incidents.

Three other Agencies (Department of Pesticide Regulation, Department of Fish and Game, and U.S. Geological Survey) also have ongoing monitoring programs and collected some pesticide and bioassay data in the Estuary during the storm. This data has been summarized below to help provide an indication of the potential magnitude and duration of this pesticide event. Additional field work will need to be undertaken to obtain estimates of the frequency of such pulses of toxicity.

Water samples collected in this study on the Old and San Joaquin Rivers contained a number of pesticides including diazinon at concentrations between 0.25-0.47 and 0.4-0.67 ppb, respectively (Table 3). The data suggest that these pesticides predominately entered the Estuary from the San Joaquin watershed. As previously mentioned, during 1991 and 1992 the U.S. Geological Survey had a program of collecting and analyzing two day composite water samples from the San Joaquin River at Airport Way for selected pesticides (personal communication, Katherine Kuivila). Diazinon concentration averaged about 0.05 ppb for the week preceeding the storm, peaked at 0.52 ppb on 12-13 February and decreased during the succeeding week to 0.06-0.07 ppb. These values are consistent with data collected by the Regional Board and the Department of Pesticide Regulation. Water samples collected by the Regional Board at Airport Way on 17 February contained 0.28 ppb diazinon (Foe, in prep). Samples taken by the Department of Pesticide Regulation on 19 February contained 0.15 ppb diazinon.

Other potential estuarine sources of dormant sprays are the Sacramento and Mokelumne Rivers and eleven agricultural drains, including French Camp Slough, which discharge to the east side of the San Joaquin River between Highway 120 and the City of Stockton. During this time period, the U.S. Geological Survey also collected two day composite pesticide samples from the Sacramento River at the I Street bridge in the City of Sacramento. Diazinon concentrations in the Sacramento River averaged about 0.02 ppb for the week prior to the storm, peaked at 0.150 ppb on 14-15 February and gradually declined during the following week to 0.04 ppb (personal communication, Katherine Kuivila). Some of the pesticide may have come from the Feather River as diazinon concentration was 0.08 ppb there on 17 February (Table 3). Less information is available for the Mokelumne River. The River was not toxic on either 10 or 17 February. However, water samples from the Mokelumne River were analyzed for pesticides on 17 February. Diazinon was measured at 0.02 ppb (Table 3). Finally, French Camp Slough was acutely toxic on the 10th but not the 17th of February. Diazinon concentration on 10 February was 1.22 ppb in the Slough (Table 3). No information exists on when and at what concentration diazinon peaked in French Camp Slough or whether the concentration there was similar to that in other agricultural drains on the east side of the River. However, these inputs only have small flows in comparison to the

Sacramento and San Joaquin Rivers, so they probably did not contribute significantly to the pesticide concentrations observed in the Estuary. In conclusion, although the data is limited, it suggests that pesticide concentrations measured in the southern portion of the Estuary probably originated from the San Joaquin River. Information on pesticide concentrations from the other Rivers is significant though, as it demonstrates that none of these water bodies were pesticide free. This is important as they are the only available source of estuarine dilution water.

A combination of pesticide and toxicity data suggest that the San Joaquin River transported acutely toxic water into the Estuary for at least an eight day period, 12 through 19 February. As previously noted, the Survey measured 0.5 ppb diazinon in composite samples collected at Airport Way on 12-13 February. These samples should have been acutely toxic to Ceriodaphnia (Table 5). Samples collected by the Regional Board on 17 February at Airport Way produced complete invertebrate mortality within 48 hours (Foe, in prep). Similarly, samples collected by the Department of Pesticide Regulation on 19 February at the same site and run by the Department of Fish and Game caused 100 percent mortality within 48 hours (personal communication, Robert Fujimura). In contrast, samples collected on 19 February on the San Joaquin River at Laird Park, sixteen miles upstream of Airport Way, produced no mortality within four days in tests run by both the Regional Board and the Department of Fish and Game. However, 80 percent mortality was recorded in seven days in these samples by the Regional Board. The Department of Fish and Game only ran their tests for four days. The decrease in toxicity at Laird Park on 19 February, as compared to Airport Way on the same date, suggests that water quality in the San Joaquin River was improving and the River's discharge to the Estuary was unlikely to remain acutely toxic much longer. In conclusion, it appears that the San Joaquin River transported acutely toxic water into the Estuary for about eight days, 12 through 19 February, 1992.

Only the San Joaquin River at Bowman Road remained toxic a week later. Water samples collected on 24 February produced 100 percent mortality within 7 days. The source of this water is not clear. Either it came into the Estuary after the 19th or it may have been part of the previous week's plug of toxic water and remained moving back and forth in the tidal prism along the San Joaquin River.

The hydrology of the Delta is complex. Net flow for the hydrologic conditions which existed in the Estuary for 12 through 19 February, 1992, is illustrated in Figure 5 (personal communication, Gordon Enas). The figure suggests that toxicity and pesticide concentrations similar to those measured on the Old and San Joaquin Rivers may have swept as far north on the San Joaquin as Empire Tract and Venice Island before encountering Mokelumne and Sacramento River flow. Water from both sources should have either diluted the pesticides and reduced or eliminated invertebrate toxicity or pinched off parcels of San Joaquin River water and carried them unmixed along with Sacramento River water across the Central Delta to the two large pump facilities at Tracy. Therefore, the primary area of impact from orchard pesticides was most likely confined to waterways in the southern Delta. Some lesser impacts may have occurred in the Central Delta.

The ecological impact of pulses of toxic pesticide water on aquatic biota in the Estuary is unknown. However, if impacts are occurring, they should be evident among species sensitive to pesticides such as amphipod, copepod, cladoceran and



rotifers. An analysis of fifteen years of Department of Fish and Game zooplankton tow data was recently completed (Obrebski *et al.*, 1992). The analysis is particularly valuable as it eliminates the impact of salinity (flow) and seasonality, two variables that have confounded all previous analyses. The study demonstrates a decline in abundance of zooplankton species (copepod, cladoceran and rotifers) in all areas of the Estuary but particularly the freshwater side. The cause of these declines is not known. Some of the decreases may be caused by pesticides entering the freshwater side of the Estuary in winter storms.

The ecological threat that dormant spraying poses to the aquatic environment may increase in the future. To date, parathion has been the most widely used dormant spray (Table 6). In 1991 it comprised half (by weight) of all spray applied, yet was seldom detected in surface water in this study (Table 3). Diazinon was the next most common insecticide and accounted for about a quarter of all dormant spray use on orchards. It was also the most common insecticide in surface water. In 1990 the U.S. EPA banned the use of parathion on orchards after 1991 because of human health concerns. The ban should increase the amount of all the other sprays applied on orchards. In particular, increased applications of diazinon should increase the amount of chemical being transported off-site and this should increase the threat it poses to the aquatic environment.

#### ALFALFA STUDY--Rainfall pattern

The spring of 1992 was unusually dry. Only three small to intermediate sized rainstorms occurred during the alfalfa portion of the study (Figure 6). The first of these was a 0.7 inch event which hit four days before the first sampling date. The other two occurred one to two days prior to other sampling events and produced 0.3 and 0.6 inches of rain. Therefore, the alfalfa study is thought to predominately represent water quality during a dry spring period.

#### Toxicity

Less toxicity was observed in the alfalfa than in the orchard portion of the study. This was true when the data are evaluated in terms of both frequency and magnitude of impairments. Thirteen percent of the samples collected during the alfalfa study (13 of 103) were classified as toxic (Table 8). Only four of these produced 100 percent mortality within twenty-four hours. In contrast, 33 percent of the orchard samples were classified as toxic and thirteen of these (18 %) produced complete invertebrate mortality within twenty-four hours (Table 3).

Toxicity was observed in only two small watersheds, Ulati Creek and Bishop Tract Main drain (Table 8). Ulati Creek tested toxic on three occasions. One hundred percent mortality was observed within one day in samples collected on both 16 and 23 March. Seventy percent mortality was measured in seven days in a Creek sample taken on 6 April. Bishop Tract Main Drain was toxic twice. One hundred percent invertebrate mortality was measured here in 24 and 48 hours in samples taken on 16 and 23 March, respectively.

Only sporadic toxicity was observed in seven day tests in waterways in the Estuary (Table 8). Eight samples tested toxic. Water samples from Paradise Cut were toxic half of the time (9 and 16 March and 13 and 20 April). Toxicity was

only measured once in four of the other six waterways. Samples collected at Old River on 16 March caused 100 percent mortality in seven days. This toxicity may have resulted from the same constituent(s) that caused invertebrate mortality at Paradise Cut on the same date because both sites are about two miles apart on Old River. The source and identity of these contaminants are not known. In contrast, the toxicity observed at the Cut on the other three dates seems most likely to have originated from contaminants released by one or more of the seven agricultural drains which discharge to Paradise Cut as no similar toxicity was observed on Old River. Water samples collected from Bishop Cut on 13 April produced 100 percent mortality in 24 hours. This was the most toxic sample collected in the Delta during the alfalfa study. Finally, both the Delta Mendota Canal at Byron Road and Cache Slough at Ryer Island were toxic on 20 April. Water samples from both sites elicited 30 percent mortality within seven days.

There was no apparent relationship between invertebrate toxicity and precipitation as the magnitude and frequency of toxicity was similar during wet and dry periods. Fifty-four percent of the water samples collected after rainstorms were classified as toxic in comparison to forty-six percent of those taken during dry periods. This difference was not significant (Chi-square,  $P > 0.05$ ).

#### Pesticide Analysis

Eleven samples were submitted for analysis. Ten of these previously had tested toxic. One was non-toxic. Diuron, diazinon, chlorpyrifos, and carbofuran were detected in the toxic samples. Diazinon was measured at 0.24 ppb in Ulati Creek on 6 April and is thought to be high enough to explain the observed invertebrate response. The carbofuran concentrations of 1.0 ppb in Ulati Creek on 23 March and of 1.9 ppb in Bishop Cut on 13 April may account for part of the toxicity measured at the sites. None of the other chemical detections are thought to be sufficiently elevated to explain any of the observed bioassay response. The lack of success which was encountered in explaining toxicity in the alfalfa study is in marked contrast to that obtained in the orchard study. Some of this failure is undoubtedly due to the fact that the pesticide analysis primarily targeted insecticides associated with alfalfa weevil control. Apparently, off-target movement of alfalfa insecticides was either much lower than in previous years or does not occur in these watersheds. Pesticide application rates on other crops are known to increase in the spring and so some of the toxicity observed in the alfalfa study may have been caused by pesticide applications on other crops. Additional work needs to be undertaken to identify these compounds.

A water sample collected on 13 April at Bishop Tract Main Drain that tested non-toxic (Table 8) was submitted to the U.S. Geological Survey for pesticide analysis. No insecticide was detected.

The primary use of carbofuran in March and April is on alfalfa, sugarbeets and grapes (Department of Pesticide Regulation, 1990 a,b). All three commodities are grown in the watersheds where carbofuran was detected. The source, therefore, of the chemical is not known for sure. Diazinon was detected in samples collected from Old River, Ulati Creek, and Bishop Cut (Table 8). The major use of diazinon in March and April is on alfalfa. However, the chemical may have

originated from earlier applications on orchards. As with carbofuran, additional work needs to be undertaken to establish the source of the diazinon.

### Ecological Significance

Over one million acres of alfalfa are harvested each year in California (Department of Commerce, 1987). The crop is grown in almost every county. About 800,000 acres are grown in the Central Valley. Other major areas of alfalfa cultivation are in the mountainous northeast of the State, coastal areas and the low desert region of southern California (University of California, 1981).

Alfalfa is a perennial crop and remains in a field for three to four years. It has a dense foliage and a high protein content. As a result, the crop provides a stable habitat for a large number of different kinds of organisms. Two of these, the Alfalfa and Egyptian Alfalfa weevil, are major alfalfa pests. Larvae of both species damage the plant by feeding on shoots prior to the first spring alfalfa cutting. In the Central Valley, weevils are controlled by spray programs in March. Pesticide application programs differ somewhat in other parts of the State. In the mountainous northeast, including the Modoc Plateau, insect development rates are slower because of freezing temperatures later in the year, so spray programs are delayed accordingly. In contrast, in the southern desert, weevil activity is largely confined to January and February (University of California, 1981).

Half a million pounds of insecticide was applied statewide on alfalfa during the first quarter of 1990 (Department of Pesticide Regulation, 1990b). Most of this was for weevil control. The principal insecticides were malathion (144,305 lbs active ingredient), chlorpyrifos (105,265 lbs), carbofuran (100,255 lbs), dimethoate (75,919 lbs), phosmet (53,446 lbs) and diazinon (24,158 lbs). Smaller amounts of a number of other insecticides including methidathion (10,351 lbs), permithrin (7,977 lbs) and methomyl (6,281 lbs) were also applied. Most applications were by ground rig or aircraft.

Most rain in California falls between October and March. Smaller amounts of precipitation are expected in April and May. For example, average annual<sup>12</sup> rainfall at the City of Stockton is 16.57 inches (City of Stockton, 1992). Mean precipitation during March, April, and May is 2.07, 0.42 and 0.43 inches. The principal ecological danger of applying large quantities of insecticide on alfalfa in California in March is that, like applications on orchards, it co-occurs with the rainy season. This increases the chance of insecticide runoff into surface water.

Results from this study suggest that pesticide applications on alfalfa may cause some impairments in waterbodies tributary to and within the Estuary itself. These problems appear less severe than those caused by dormant spray applications on orchards. However, it must be borne in mind that the testing was conducted during different precipitation regimens. The applications on orchards were followed by a wet month while those on alfalfa occurred during a dry period.

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<sup>12</sup>1948 to 1978.

More monitoring needs to be undertaken to verify the alfalfa finding for dry years and better ascertain what occurs during wet ones.

Surface water monitoring during the previous several years has detected insecticides which were tentatively attributed to applications on alfalfa. In April, 1990, carbofuran and diazinon were measured in water samples collected along 36 miles of San Joaquin River at concentrations between 0.54-0.61 and 1.06-1.53 ppb, respectively (Foe, 1990b). In 1991 and 92, Regional Board staff monitored creeks, agricultural drains, and all rivers tributary to the San Joaquin River south of Airport Way weekly for invertebrate toxicity and pesticides (Foe, in prep). In both years some toxicity and pesticides were observed in creeks and agricultural drains which could be attributed to alfalfa runoff. In 1992 the insecticides may have caused Ceriodaphnia toxicity in both Salt Slough and the San Joaquin River (Foe, in prep).

As previously mentioned, during 1991 and 92 the U.S. Geological Survey collected daily samples at Airport Way on the San Joaquin River, composited them into two day aliquots, and analyzed the water for selected pesticides. In 1991 diazinon and carbofuran were observed for about 20 days in March at concentrations between 0.01-0.08 and 0.03-0.09 ppb, respectively (personal communication, Kathy Kuivila). The pesticides are attributed to applications on alfalfa. No similar well defined increase in alfalfa insecticides was observed in 1992. Increased concentrations at Airport Way in March 1991, but not 1992, may have been due to the large amount of precipitation which occurred during the first but not the second year. If so, the finding is similar to the observation obtained in the orchard portion of the present study. Large amounts of precipitation may increase the efficiency of pesticide movement from agricultural areas to surface water. The observation is important as increases in ambient pesticide concentrations increase the potential for causing instream toxicity.

The U.S. Geological Survey also monitored organophosphate and carbamate pesticide concentrations at four locations in the Estuary during April 1991. A pattern of increasing carbofuran was observed westward in the Estuary (personal communication, Kathy Kuivila). Concentrations at Chipps Island varied between 0.08 and 0.25 ppb. The carbofuran is assumed to result from applications on alfalfa, although the precise concentrations and locations of runoff remain unclear. This pattern was not repeated in 1992. Data from the alfalfa portion of the present study support the U.S. Geological Survey findings of little carbofuran in the Estuary during the spring of 1992.

#### Regulatory limits for orchard and alfalfa pesticides

The Basin Plan has a narrative objective of no toxicity in surface waters including major agricultural drains, creeks, rivers and the Estuary. All the incidents of toxicity measured in this study are thought to be a violation of the narrative objective.

Eleven pesticides were detected in this study (Table 9). No regulatory limits exist in the Basin Plan for any of these compounds except carbofuran and malathion. The Basin Plan has malathion and carbofuran performance goals of 0.1 and 0.4 ppb. None of the three malathion detections exceeded the performance goal while both of the carbofuran ones did.

Recommended criteria to protect freshwater aquatic life exist for diazinon, diuron, parathion, and chlorpyrifos (Table 9). All twenty-nine diazinon detections exceeded the National Academy of Science (1972) recommended maximum criterion of 0.009 ppb (Figure 7). Both parathion detections of 0.01 ppb were at the EPA recommended four day criterion level of 0.013 ppb (EPA, 1986a). All chlorpyrifos measurements were below the lowest recommended criterion (EPA, 1986b; Table 9). Eighteen of the twenty-three diuron measurements were above the National Academy of Science (1972) recommended criterion of 1.6 ppb (Table 9). No criteria exist for evaluating the concentration of bromocil, methidathion, diazinon-oxon, protham, or fluometuron.

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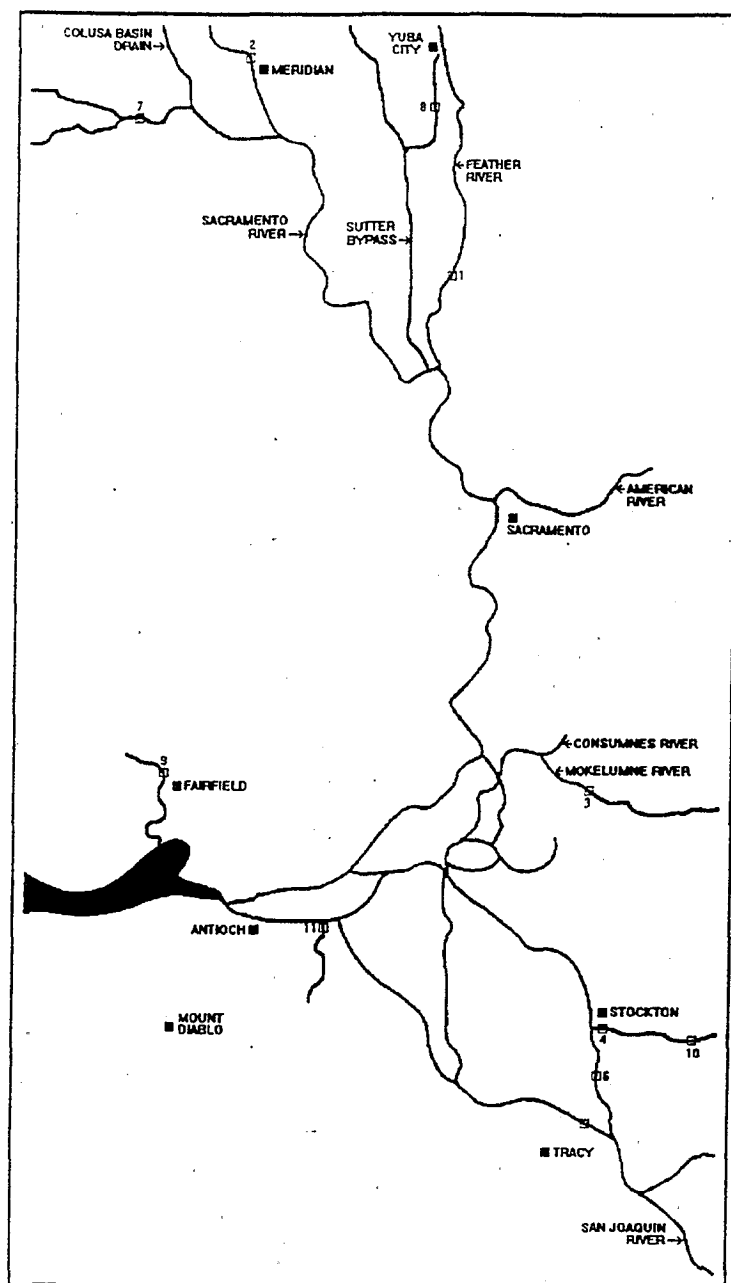
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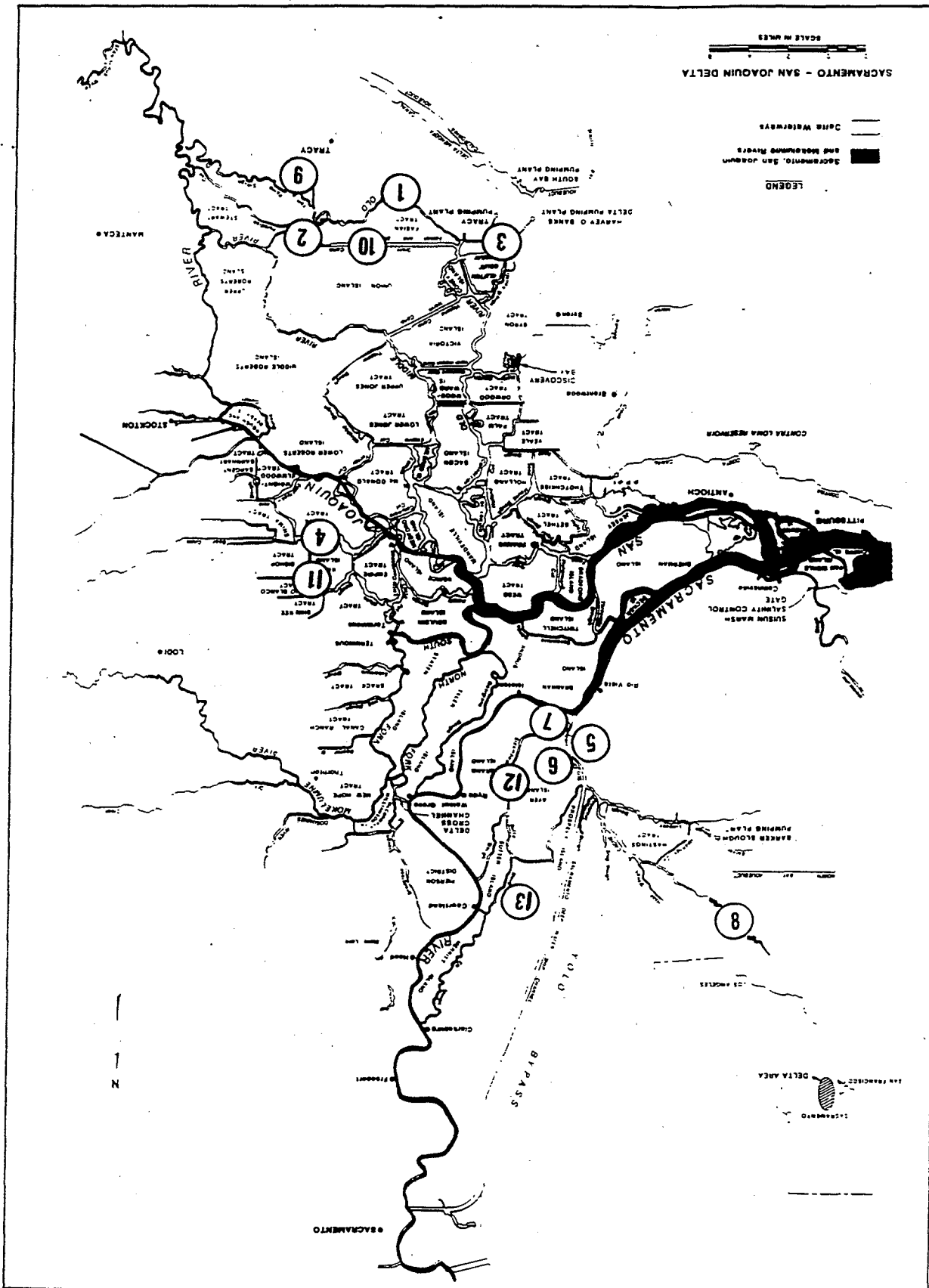
Site No.	Location
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- |     |                    |
|-----|--------------------|
| 1.  | Feather River      |
| 2.  | Sacramento River   |
| 3.  | Mokelumne River    |
| 4.  | French Camp Slough |
| 5.  | Old River          |
| 6.  | San Joaquin River  |
| 7.  | Clark's Ditch      |
| 8.  | Gilsizer Slough    |
| 9.  | Ledgewood Creek    |
| 10. | Lone Tree Creek    |
| 11. | Marsh Creek        |
- 

Figure 1. Map of orchard sampling sites. The location of each station is described in Appendix B.

Figure 2. Sampling sites for the alfalfa portion of this study. Site locations are described in Appendix D. Template of Delta is from Department of Water Resources (1987).



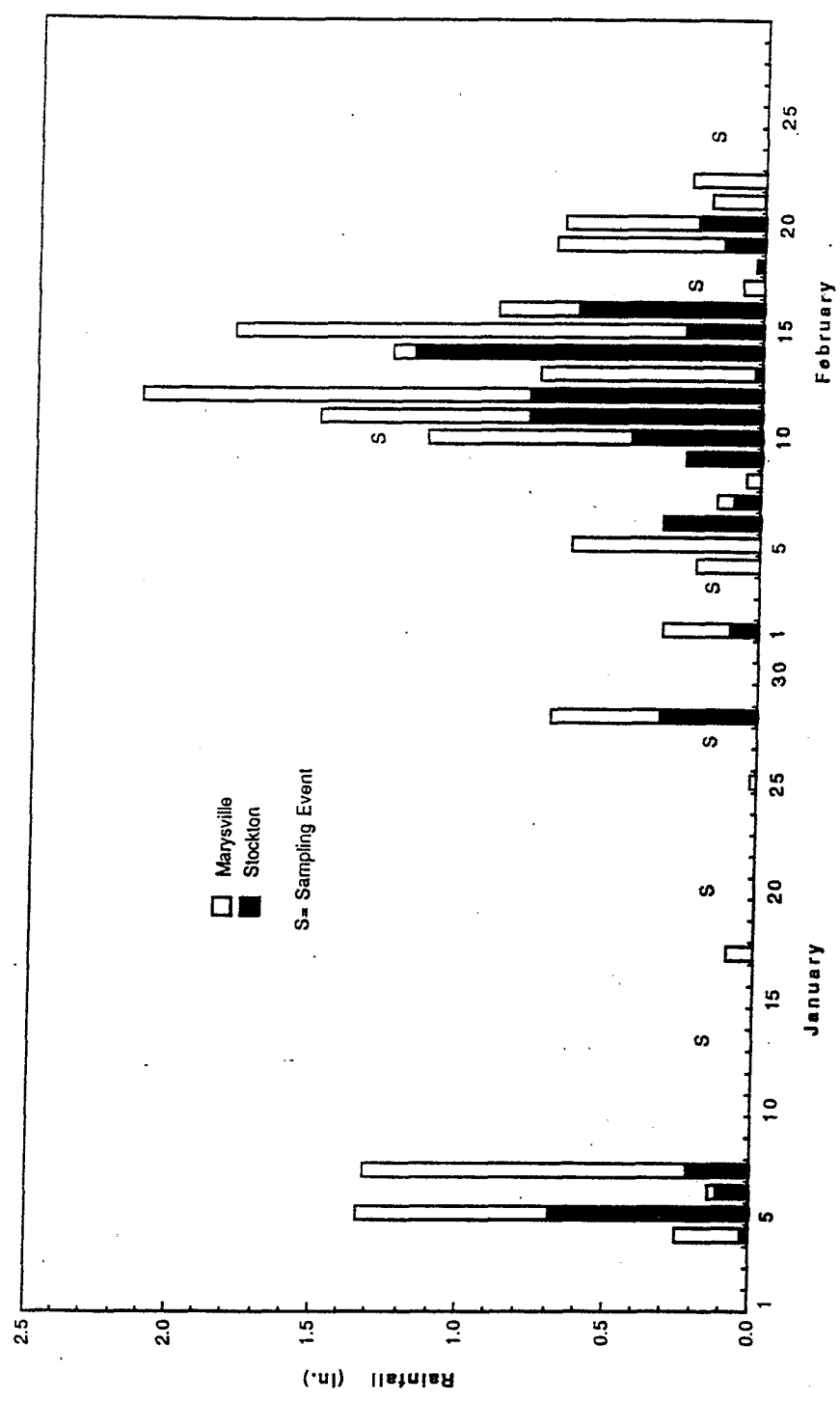
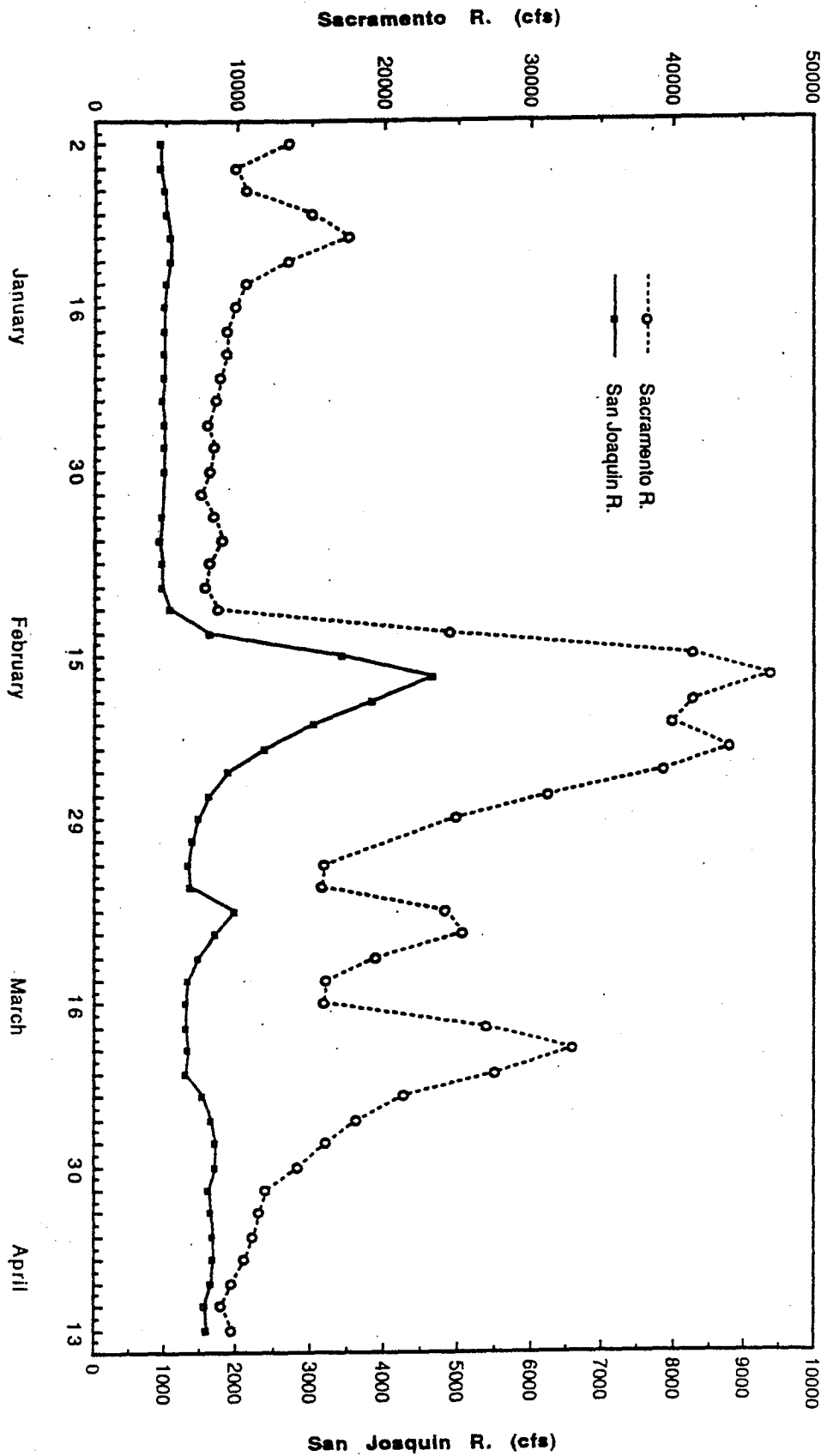


Figure 3. Precipitation pattern in the Central Valley during the orchard part of the study. Sampling occurred each Monday and is indicated by the letter "S". Rainfall data is from the U.S. Department of Commerce (NOAA) for the City of Stockton Weather Service Office and from the Fire Station in the City of Marysville.

Figure 4. Two day average flow for the Sacramento River at the Freeport Bridge and for the San Joaquin River at Airport Way for the time period of 1 January through 15 April, 1992.



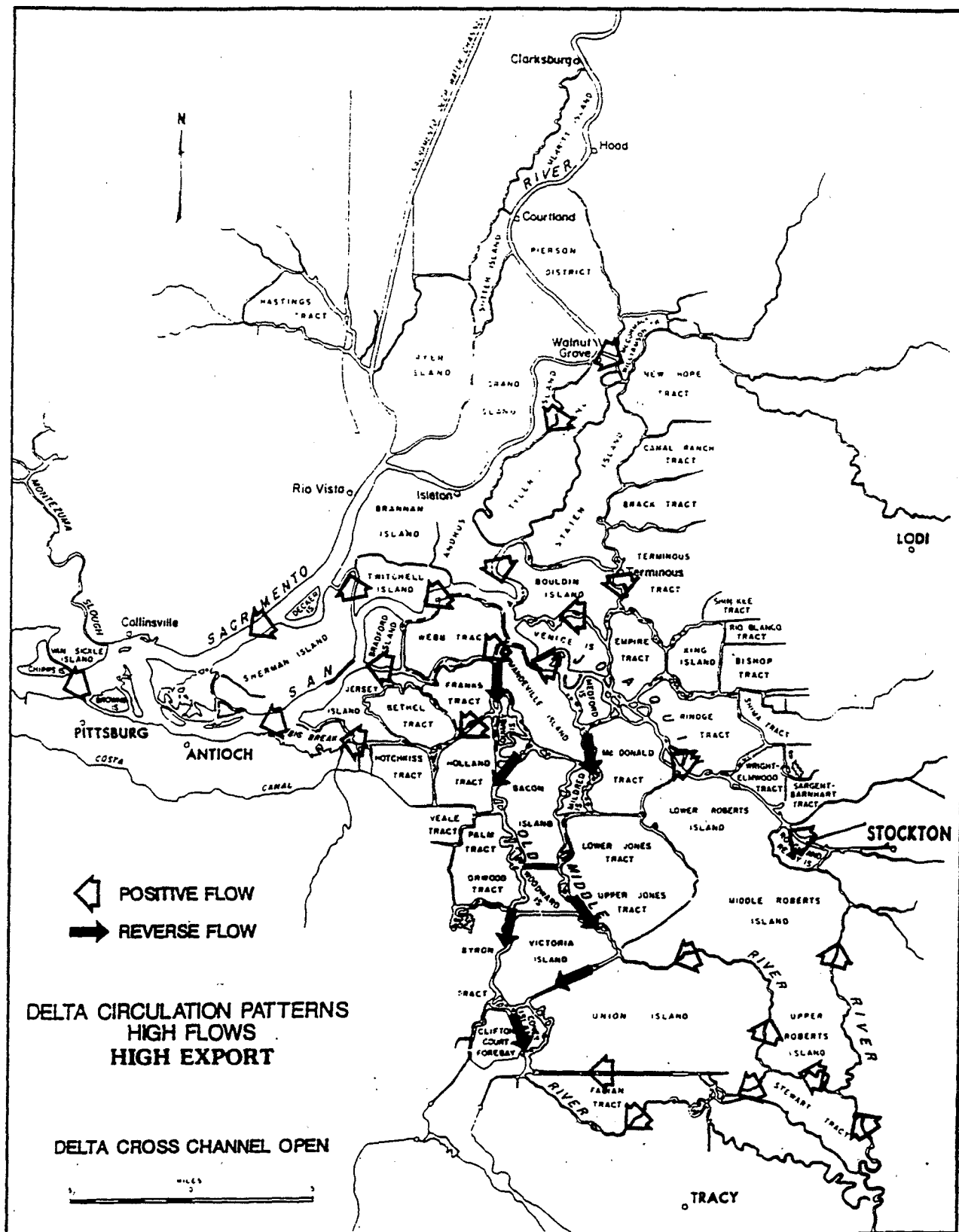


Figure 5. Water circulation pattern in the Sacramento-San Joaquin Delta Estuary for the flow and export conditions prevailing between 12 and 19 February, 1992. The circulation pattern corresponds to a "high flow-high export" scenario. Template is from Department of Water Resources Exhibit 51E to the State Water Resources Control Board, Phase I, Bay Delta Hearings.

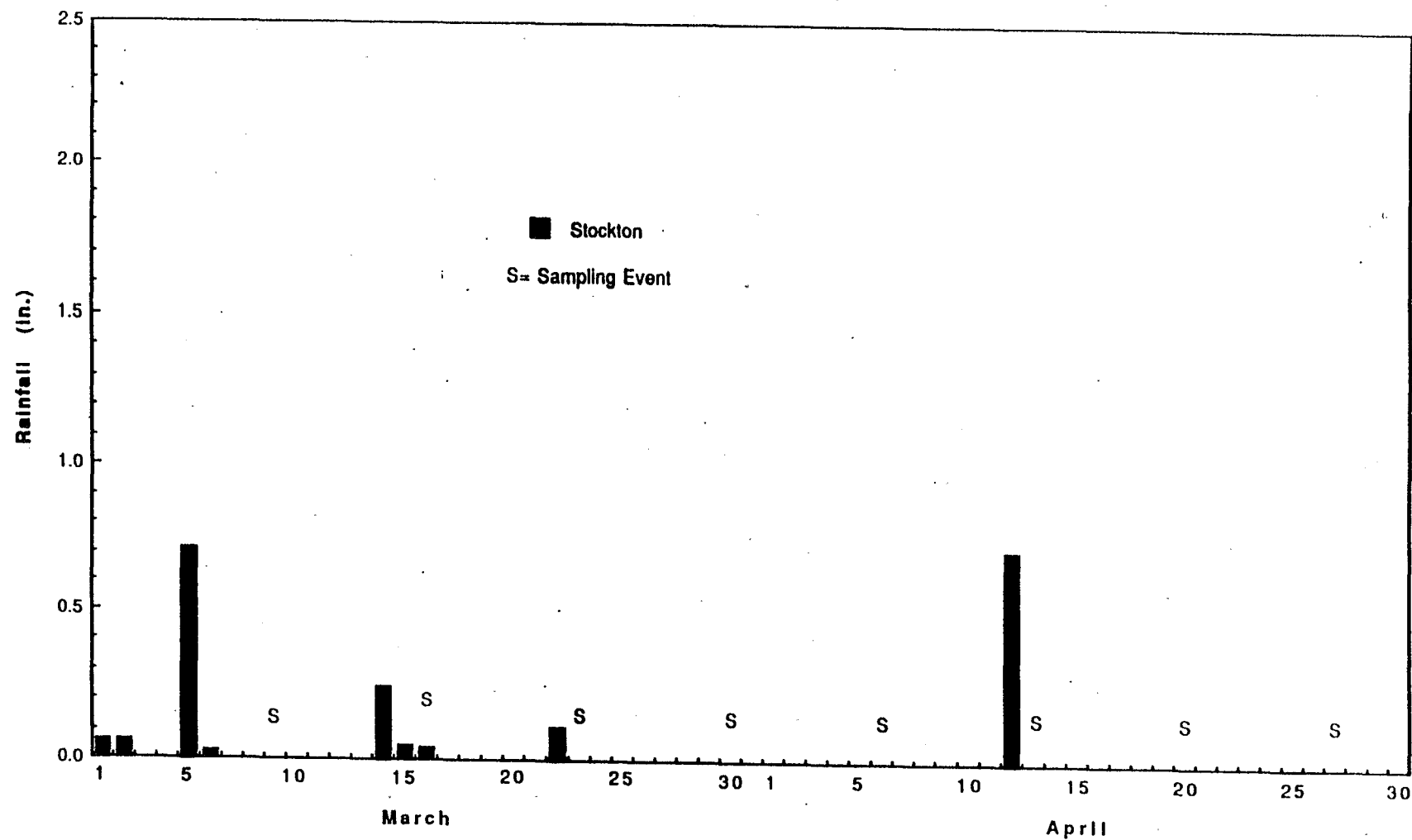


Figure 6. Precipitation pattern in the Sacramento-San Joaquin Delta Estuary during the alfalfa part of the study. Sampling occurred each Monday and is indicated by the letter "S". Rainfall data is from the U.S. Department of Commerce (NOAA) for the City of Stockton Weather Service Office.

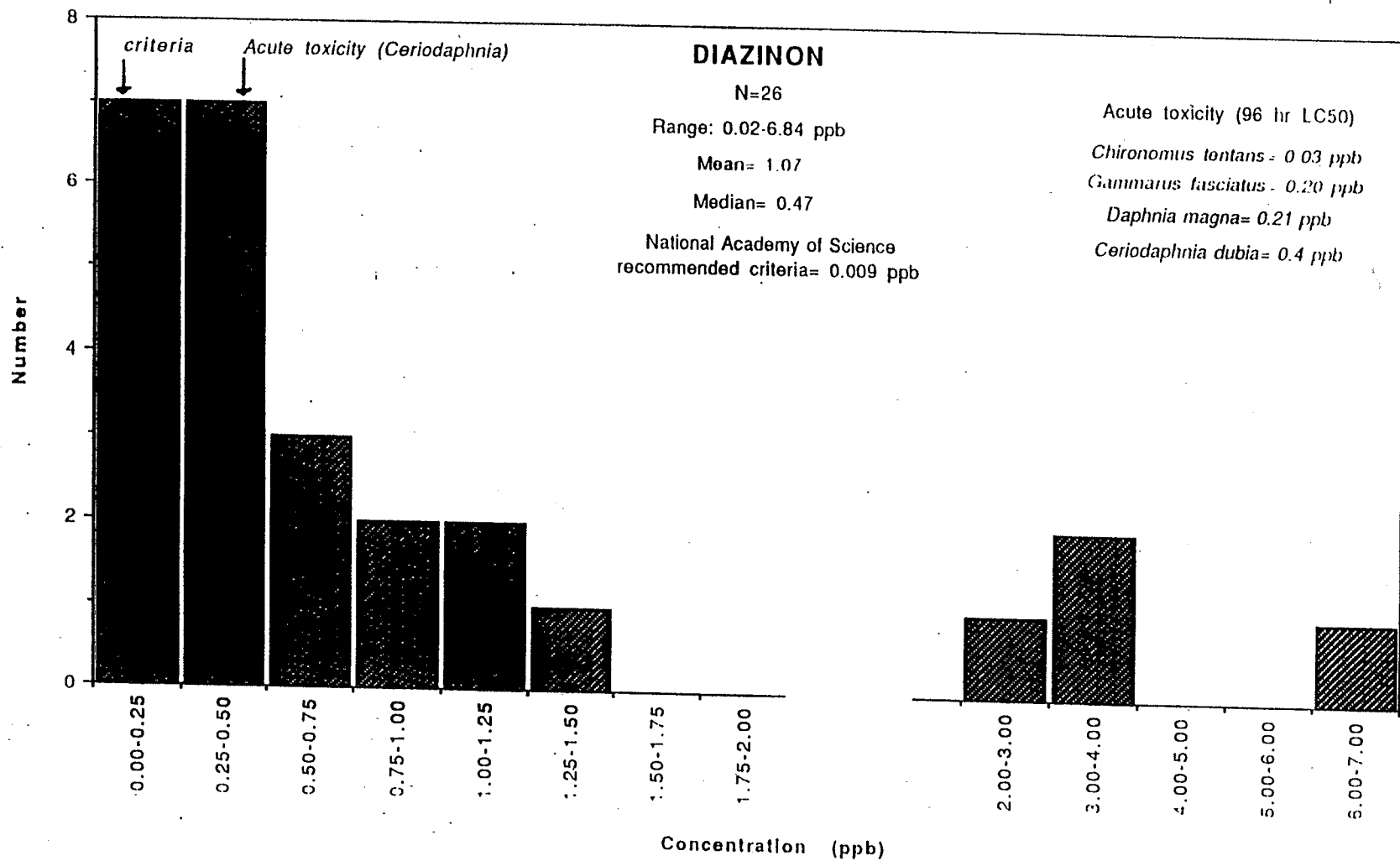


Figure 7. Histogram of diazinon concentrations reported in this study. Also included are the National Academy of Science (1972) recommended criteria to protect freshwater aquatic life and selected toxicity values reported in the literature for aquatic organisms (Sheipline, in prep).

Table 1. Land use patterns for small drainage basins monitored in the orchard portion of the study. Land use data was estimated from the Department of Water Resources land use maps.

CROPS	DRAINAGE BASIN (ACRES)					
	Ledgewood Creek <sup>2</sup>	Marsh Creek <sup>2</sup>	Gilsizer Slough <sup>4</sup>	Lone Tree Creek <sup>5</sup>	French Camp Slough <sup>5</sup>	Clark's Ditch <sup>3</sup>
Orchards						
Pears	1,000		<sup>1/</sup>			
Prune/plums	1,000	<sup>1/</sup>	6,500			
Almonds		3,500	<sup>1/</sup>	9,000	10,000	2,000
Apricots	<sup>1/</sup>					
Peaches/nectarines			5,500			
Cherries		<sup>1/</sup>		<sup>1/</sup>	<sup>1/</sup>	
Apples						
Walnuts	1,000	3,500	3,500	<sup>1/</sup>	9,000	<sup>1/</sup>
Field & Row Crops <sup>6</sup>	2,000	3,000	2,500	29,000	83,000	3,000
Vineyards	<sup>1/</sup>	<sup>1/</sup>		9,000	10,000	
Native Vegetation	5,000	47,500		<sup>1/</sup>	9,000	3,000
Urban		3,500	2,000		1,000	
Dairies				<sup>1/</sup>	<sup>1/</sup>	
Total Drainage	10,000	67,000	22,000	58,000	134,000	8,500

<sup>1/</sup> Small acreage (1-3 percent of area).

<sup>3/</sup> Land use survey conducted in 1985.

<sup>5/</sup> Land use survey conducted in 1988.

<sup>2/</sup> Land use survey conducted in 1987.

<sup>4/</sup> Land use survey conducted in 1984.

<sup>6/</sup> Probably planted in either grain or left fallow during the study.



Table 2. Summary of percent Ceriodaphnia survival in water samples collected as part of the orchard study. Toxicity is defined as any sample with 30 percent more death than the laboratory control. These events are indicated by shading.

Station	DATE (1992)						
	1/13	1/20	1/27	2/3	2/10	2/17	2/24
Feather R @ Lee Rd <sup>1</sup>	100	100	100	100	50	100	70
Sacramento R @ Meridian <sup>1</sup>	100	100	100	90	100	100	100
Mokelumne R @ New Hope <sup>1</sup>	100	100	30	0	100	100	100
French Camp Sl @ Manthey <sup>1</sup>	0	100	0	0	0	100	100
Old R @ Cohen Rd <sup>1</sup>	80	100	100	100	80	0	100
San Joaquin R @ Bowman Rd <sup>1</sup>	100	100	90	100	100	0	0
Clark's Ditch @ White Rd <sup>2</sup>	no flow				0	0	0
Gilsizer Sl @ Washington Rd <sup>2</sup>	100	100	0	0	0	0	0
Ledgewood Ck @ Portsmouth <sup>2</sup>	100	100	100	100	0	100	100
Lone Tree Ck @ Austin Rd <sup>2</sup>	90	40	0	0	0	0	100
Marsh Ck @ Cypress Rd <sup>2</sup>		100	100	100	70	100	100
Laboratory Ctl <sup>1</sup>	100	100	100	100	100	100	100

<sup>1</sup> Seven day bioassay test. <sup>2</sup> Four day bioassay test.

Table 3. *Ceriodaphnia* bioassay results for orchard portion of study. Shaded sites were classified as toxic. Organophosphate and carbamate pesticide analysis was only conducted routinely on water samples classified as toxic. Chemical analysis was performed by Eureka Laboratory unless noted otherwise. Also listed is the amount of bioassay toxicity which can be explained by the measured pesticide concentrations.

Date: 13 January 1992									
Station	<i>Ceriodaphnia</i> survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained <sup>1</sup>
Feather R @ Lee Rd	100	100	100	100	100	100	100		
Sacramento R @ Meridian	100	100	100	100	100	100	100		
Mokelumne R @ New Hope	100	100	100	100	100	100	100		
French Camp Sl @ Hanthey	100	100	100	100	80	30	0	diuron=5.0 bromocil=7.5 organophosphate=nd	negligible
Old R @ Cohen Rd	90 <sup>2</sup>	90	90	90	90	80	80		
San Joaquin R @ Bowman Rd	100	100	100	100	100	100	100		
Clark's Ditch @ White Rd	no flow								
Gilsizer Sl @ Geo. Washington Rd	100	100	100	100					
Ledgewood Ck @ Portsmouth Ct	100	100	100	100					
Lone Tree Ck @ Austin Rd	100	100	100	90					
Marsh Ck @ Cypress Rd	no sample								
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> One animal accidentally killed by laboratory personnel. <sup>3</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 3. (Continued)

Date: 20 January 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained <sup>2</sup>
Feather R @ Lee Rd	100	100	100	100	100	100	100		
Sacramento R @ Meridian	100	100	100	100	100	100	100		
Mokelumne R @ New Hope Rd	100	100	100	100	100	100	100		
French Camp Sl @ Manthey	100	100	100	100	100	100	100		
Old R @ Cohen Rd	100	100	100	100	100	100	100		
San Joaquin R @ Bowman Rd	100	100	100	100	100	100	100		
Clark's Ditch @ White Rd	no flow								
Gilsizer Sl @ Geo. Washington Rd	100	100	100	100					
Ledgewood Ck @ Portsmouth Ct	100	100	100	100					
Lone Tree Ck @ Austin Rd	100	100	90	40				diazinon=0.12 diuron=2.92	partial
Marsh Ck @ Cypress Rd	100	100	100	100					
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 3. (Continued)

Date: 27 January 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of Toxicity explained <sup>2</sup>
Feather R @ Lee Rd	100	100	100	100	100	100	100		
Sacramento R @ Meridian	100	100	100	100	100	100	100		
Hokeluma R @ New Hope Rd	100	100	100	100	100	30	30	diazinon=0.23 carbamates=nd	partial
French Camp Sl @ Manthey	100	0	0	0	0	0	0	diazinon=0.46 diuron=2.06	partial
Old R @ Cohen Rd	100	100	100	100	100	100	100		
San Joaquin R @ Bowman Rd	100	100	100	100	100	90	90		
Clark's Ditch @ White Rd	no flow								
Gilsizer Sl @ Geo. Washington Rd	0	0	0	0				diazinon=0.83 methidathion=0.15 diuron=6.20	complete
Ledgewood Ck @ Portsmouth Ct	100	100	100	100					
Lone Tree Ck @ Austin Rd	0	0	0	0				diazinon=1.04 diuron=1.27	complete
Marsh Ck @ Cypress Rd	100	100	100	100					
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

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Table 3. (Continued).

Date: 3 February 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained <sup>2</sup>
Feather R @ Lee Rd	100	100	100	100	100	100	100		
Sacramento R @ Meridian	100	90	90	90	90	90	90		
Mokelumne R @ New Hope Rd	90	0	0	0	0	0	0	carbamates=nd=organophosphate	negligible
French Camp Sl @ Manthey	90	30	10	0	0	0	0	diazinon=0.25 diuron=0.70	partial
Old R @ Cohen Rd	100	100	100	100	100	100	100	diazinon=0.1 <sup>3</sup>	
San Joaquin R @ Bowman Rd	100	100	100	100	100	100	100	diazinon=0.04 <sup>3</sup>	
Clark's Ditch @ White Rd	no flow								
Gilsize Sl @ Geo. Washington Rd	0	0	0	0				diuron=30.6 diazinon=3.97 methidathion=2.17	complete
Ledgewood Ck @ Portsmouth Ct	100	100	100	100					
Lone Tree Ck @ Austin Rd	0	0	0	0				diuron=0.9 diazinon=0.98 methidathion=0.14	complete
Marsh Ck @ Cypress Rd	100	100	100	100					
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>3</sup> U.S. Geological Survey <sup>5</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 3. (Continued).

Date: 10 February 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained <sup>1</sup>
Feather R @ Lee Rd	90	70	50	50	50	50	50	carbamates=nd=organophosphate pesticides	negligible
Sacramento R @ Meridian	100	100	100	100	100	100	100		
Mokelumne R @ New Hope Rd	100	100	100	100	100	100	100		
French Camp Sl @ Manthey	0	0	0	0	0	0	0	diazinon=1.22 diuron=8.1 bromocil=2.41 methidathion=0.66 <sup>4</sup>	complete
French Camp Sl @ Manthey -- pesticide split	Department of Pesticide Regulation							diazinon=0.43 diazinon=1.26 methidathion=0.19	
French Camp Sl @ Manthey -- pesticide split	U.S. Geological Survey							diazinon=0.85 malathion=0.04	
Old R @ Cohen Rd	90	90	90	90	90	80	80		
San Joaquin R @ Bowman Rd	100	100	100	100	100	100	100		
Clark's Ditch @ White Rd	10	0	0	0				diazinon=0.44 methidathion=0.97 diuron=0.10	partial
Gilster Sl @ Geo. Washington Rd	0	0	0	0				diazinon=3.39 methidathion=15.1 diuron=15.8	complete
Ledgewood Ck @ Portsmouth Ct	100	70	10	0				diazinon=0.30 methidathion=0.32 diuron=6.5	partial
Lone Tree Ck @ Austin Rd	0	0	0	0				diazinon=2.79 diuron=6.1 bromocil=1.32 methidathion=2.45	complete
Marsh Ck @ Cypress Rd	100	80	80	80	70	70		diazinon=0.28 diuron=4.5	complete
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> Water samples were split with U.S. Geological Survey's Central Laboratory at Denver and California Department of Pesticide Regulation's Sacramento Laboratory for organophosphate analysis. The Survey does not analyze for methidathion or diazinon. Eureka and Department of Pesticide Regulation detection limits are set at 0.05 ppb. <sup>4</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 3. (Continued).

Date: 17 February 1992										
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained	
Feather R @ Lee Rd	100	100	100	100	100	100	100	diazinon=0.08'		
Sacramento R @ Meridian	100	100	100	100	100	100	100			
Mokelumne R @ New Hope Rd	100	100	100	100	100	100	100	diazinon=0.02'		
French Camp Sl @ Manthey	100	100	100	100	100	100	100			
Old R @ Cohen Rd	0	0	0	0	0	0	0	diuron=2.5 diazinon=0.47 propham=17.7'	partial	
Old R @ Cohen Rd --pesticide split	Department of Pesticide Regulation							diazinon=0.35 methidathion=0.13		
Old R @ Cohen Rd --pesticide split	U.S. Geological Survey							diazinon=0.25 malathion=0.01 parathion=0.01		
San Joaquin R @ Bowman Rd	0	0	0	0	0	0	0	diuron=2.8 diazinon=0.67 propham=9.2 methidathion=0.14'	partial	
San Joaquin R @ Bowman Rd -- pesticide split	Department of Pesticide Regulation							diazinon=0.47 methidathion=0.23		
San Joaquin R @ Bowman Rd -- pesticide split	U.S. Geological Survey							diazinon=0.4 chlorpyrifos=0.01 malathion=0.01 parathion=0.01		
Clark's Ditch @ White Rd	0	0	0	0				diuron=19.0, propham=3.6 flurmeturon=3.0 diazinon=1.41 methidathion=0.32	complete	
Glisizer Sl @ Geo. Washington Rd	0	0	0	0				diuron=7.1 diazinon=6.84 propham=19.9 methidathion=1.44	complete	
Ledgewood Ck @ Portsmouth Ct	100	100	100	100						
Lone Tree Ck @ Austin Rd	100	100	0	0				diuron=2.6 diazinon=0.32 propham=10.7	partial	
Marsh Ck @ Cypress Rd	100	100	100	100						
Laboratory Ctl	100	100	100	100	100	100	100			

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> U.S. Geological Survey <sup>4</sup> Methidathion is not in the Survey's scan. Eureka and Department of Pesticide Regulation's reporting limits are 0.05 ppb.

Table 3. (Continued).

Date: 24 February 1992											
Station	Ceriodaphnia survival (%) by day					Pesticide detections <sup>1</sup> (ppb)		Amount of toxicity <sup>5</sup> explained <sup>5</sup>			
	100	100	100	100	70	70	70				
Feather R a Lee Rd	100	100	100	100	70	70	70				
Sacramento R a Meridian	100	100	100	100	100	100	100				
Mokelumne R a New Hope Rd	100	100	100	100	100	100	100				
French Camp St a Manthey	100	100	100	100	100	100	100				
Old R a Cohen Rd	100	100	100	100	100	100	100				
San Joaquin R a Bowman Rd	100	100	100	100	100	30	0	diazinon=0.4 <sup>2</sup> diuron=1.6 <sup>3</sup>	complete		
Clark's Ditch a White Rd	0	0	0	0	0			diazinon=0.66 diuron=1.2	partial		
Glitszer St a Dep. Washington Rd	0	0	0	0	0			diazinon=0.51 diuron=9.0	partial		
Ledgewood Ck a Portsmouth Ct	100	100	100	100	100						
Lone Tree Ck a Austin Rd	100	100	100	100	100						
Marsh Ck a Cypress Rd	100	100	100	100	100						
Laboratory Ctl											
	90	90	90	90	90	80	80				

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> U.S. Geological Survey analyzed sample. <sup>3</sup> One animal killed accidentally by laboratory personnel. <sup>4</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity. <sup>5</sup> Pesticides detected toxicity.



Table 4. Mean pesticide concentration in toxic water samples collected from small water courses before<sup>1</sup>, during and after the 10 to 17 February, 1992, storm. All concentrations are in ppb.

	CONCENTRATION		
	BEFORE <sup>2</sup>	DURING	AFTER
Diazinon	1.09 + 0.50, 7	1.89 + 0.73, 9	0.59 + 0.08, 2
Methidathion	0.82 + 0.68, 3	2.68 + 2.03, 7	
Diuron	6.20 <sup>3</sup> + 3.57, 8	7.76 + 2.01, 9	5.10 + 3.90, 2

<sup>1</sup> Data employed in the "before" dates was collected on January 13, 20 and 27 and February 3, 1992. The "during" dates were collected on 10 and 17 February. The "after" date was collected on 24 February.

<sup>2</sup> Mean + 1 standard error, sample size.

<sup>3</sup> If the value of 30.6 ppb which was detected at Gilsizer Slough on 3 February 1992 is omitted, then the mean and standard error decrease to 2.72 + 0.80 ppb

Table 5. Toxicity to Ceriodaphnia dubia of pesticides detected in surface water in the orchard-alfalfa study. All pesticide concentrations are in ppb and were measured unless noted otherwise.

PESTICIDE	TOXICITY				SOURCE
	96 Hr LC <sub>50</sub> <sup>1</sup>	48 Hr LC <sub>50</sub>	24 Hr LC <sub>50</sub>	OTHER	
Diazinon	0.51, 0.47	0.43 <sup>2</sup>	0.55 <sup>2</sup>		per. comm. Robert Fujimura per. comm. Howard Bailey
				IC <sub>25</sub> <sup>3</sup> =0.12	per. comm. David Mount
Methidathion	2.4, 2.0				per. comm. Robert Fujimura
Chlorpyrifos	0.08, 0.13				per. comm. Robert Fujimura
Malathion	1.4				Norberg-King <u>et al.</u> , 1989
Carbofuran				7 da LOEC <sup>2,4</sup> =2.6 7 da NOEC <sup>2,5</sup> =1.3	Norberg-King <u>et al.</u> , 1991
Diuron	12,100				per. comm. George Issac

<sup>1</sup> Concentration causing 50% mortality in a specified time period.  
<sup>3</sup> Concentration causing a 25% reduction in reproduction in 7 days.  
<sup>5</sup> No observed effect concentration

<sup>2</sup> Nominal concentration  
<sup>4</sup> Lowest observed effect concentration

Table 6. Statewide application of dormant sprays (lbs active ingredient) on stonefruit orchards during the first quarter of 1990. Walnuts, although not a stonefruit, are included as they also receive dormant sprays. Data are from the California Department of Pesticide Regulation (1990a).

CROP	MALATHION	DIAZINON	PARATHION	CHLORPYRIFOS	METHIDATHION
Almonds	179	189,418	275,601	43,900	44,130
Apples		7,555	10,262	10,817	5,585
Apricots	30	6,617	9,978	-	1,462
Cherries	3,536	3,792	1,633	211	631
Nectarines	88	3,234	44,580	25,473	3,711
Peaches	7	10,107	123,590	9,792	11,163
Pears	67,287	592	3,102	1,015	433
Plums	34	7,867	35,333	17,594	11,627
Prunes		28,372	54,169	4,169	
Walnuts	1	379	248	286	3,864
Total	71,162	257,933	558,496	113,257	82,606
Grand Total:					1,083,454

Table 7. Summary of stonefruit orchard acreage by County. Data from U.S. Department of Commerce (1987).

COUNTY	ORCHARDS											TOTAL <sup>1</sup>
	ALMONDS	APPLES	APRICOTS	CHERRIES	NECTARINES	PEACHES	PEARS	PLUMS	PRUNES	WALNUTS	SUM OF ORCHARDS	
BUTTE	37,870	150				2,118			10,071	14,627	68,836	494,530
MODOC												729,023
SHASTA										1,175	1,175	377,352
TEHAMA	6,928					69			8,660	11,074	26,731	1,104,584
GLENN	14,659								7,229	5,681	27,569	490,732
LAKE	23	12					5,463		95	7,915	13,508	454,903
COLUSA	16,900								4,800	4,950	26,650	456,266
PLUMAS												88,000
SIERRA												51,352
NEVADA		73									73	56,179
SUTTER	4,299	411	33			7,189	648	48	20,663	14,047	47,338	355,973
YUBA	1,840					3,834			11,934	5,967	23,575	222,748
PLACER		73				80	115	700		1,030	1,998	168,223
EL DORADO		745		93		32	738	100		349	2,057	128,135
YOLO	7,546		664			119	515		2,175	6,769	17,788	505,597
SOLANO	1,686		919	76		300	1,709		2,147	3,155	9,992	321,297
SACRAMENTO							6,610			160	6,770	412,225
AMADOR									58	615	673	218,532
CALAVERAS	60	140								731	931	253,421
SAN JOAQUIN	36,600	1,170	2,570	7,330		2,333	624			27,400	78,627	823,729
STANISLAUS	69,500	1,220	7,150	1,290		10,300				25,600	115,060	719,845
TUOLUMNE		85									85	121,119
MARIPOSA		205									205	236,709
MERCED	66,342		1,657		188	3,925		278	1,835	7,622	81,847	1,049,302
MADERA	39,659	1,900			765	5,693		1,201		1,698	50,916	757,263
SAN BENITO		605	2,356	400						4,325	7,686	490,850
FRESNO	29,367		523		13,071	13,206	299	17,703	1,206	2,983	78,358	1,975,373
KINGS	3,061	257	250		1,414	3,023		1,794		4,978	14,772	702,173
TULARE	8,977	908	415		8,021	5,950	474	16,424	4,982	22,907	69,056	1,410,172
KERN	73,526	4,686	622		2,144	2,842	117	3,241		1,825	89,002	3,037,068
CONTRA COSTA	120	880	922	352	31	149	268	11		1,680	4,413	200,262
SUM OF ALL OTHERS COUNTIES	3,300	15,492	1,257	1,432	260	1,424	3,720	138	2,774	6,139	35,936	12,185,241
STATE TOTAL	422,212	29,610	20,040	12,024	25,894	59,974	20,940	41,738	78,629	185,402	896,463	30,598,178

<sup>1</sup> TOTAL AREA IN AGRICULTURAL PRODUCTION

Table 8. *Ceriodaphnia* bioassay results for alfalfa portion of study. Shaded sites were classified as toxic. Organophosphate and carbamate pesticide analysis was conducted on water samples classified as toxic. Chemical analysis was performed by Eureka Laboratory unless noted otherwise. Also listed is the amount of bioassay toxicity which can be explained by the measured pesticide concentrations.

Date: 9 March 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained <sup>2</sup>
Old R. @ Tracy Rd (Site 1)	100	100	100	100	100	100	100		
Paradise Cut @ Paradise Rd (Site 2)	100	100	100	100	80	70	40	organophosphate=nd carbamates=nd	negligible
Delta Mendota Canal @ Byron Rd (Site 3)	100	100	100	100	100	100	100		
Bishop Cut @ Eight mile Rd (Site 4)	100	100	100	100	100	100	100		
Cache Sl @ Liberty Is Rd (Site 5)	100	100	100	100	100	100	100		
Cache Sl off Ryer Island (Site 6)	100	100	100	100	100	100	100		
Steamboat Sl off Grand Island (Site 7)	100	100	100	100	100	100	100		
Ulatis Ck @ Salem Rd (Site 8)	100	100	100	100	100	100	100		
Fabian Tract main drain (Site 10)	100	100	100	100					
Bishop Tract main drain (Site 11)	100	100	100	100					
Elkhorn Sl on Ryer Island (Site 12)	100	100	100	100					
Sutter Island main drain (Site 13)	100	100	100	100					
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 8. (Continued)

Date: 16 March 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained <sup>4</sup>
Old R. @ Tracy Rd (Site 1)	100	100	100	100	20	10	0	Organophosphate=nd <sup>2</sup>	?
Old R. @ Tracy Rd -- pesticide split	U. S. Geological Survey							diazinon=0.07 carbamates=?	
Paradise Cut @ Paradise Rd (Site 2)	100	100	100	70	0	0	0	Organophosphate=nd carbamates=?	?
Delta Mendota Canal @ Byron Rd (Site 3)	100	100	100	100	100	100	100		
Bishop Cut @ Eight mile Rd (Site 4)	100	100	100	100	100	100	100		
Cache Sl @ Liberty Is Rd (Site 5)	100	100	100	100	100	100	100		
Cache Sl off Ryer Island (Site 6)	100	100	100	100	100	100	90 <sup>3</sup>		
Steamboat Sl off Grand Island (Site 7)	100	100	100	100	100	100	100		
Ulatis Ck @ Salem Rd (Site 8)	0	0	0	0	0	0	0	Organophosphate=nd diuron=3.6	negligible
Tom Paine Sl @ MacArthur Rd (Site 9)	100	100	100	90					
Fabian Tract main drain (Site 10)	100	100	100	100					
Bishop Tract main drain (Site 11)	0	0	0	0				organophosphate=nd carbamates=nd	negligible
Elkhorn Sl on Ryer Island (Site 12)	100	100	100	100					
Sutter Island main drain (Site 13)	100	100	100	90					
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> Did not send carbamate samples to Eureka Laboratory because of a lack of money. <sup>3</sup> One animal accidentally killed by laboratory personnel. <sup>4</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 8. (Continued)

Date: 23 March 1992													
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)		Amount of toxicity explained <sup>2</sup>			
	100	100	100	100	100	100	100	100	100				
Old R. a Tracy Rd (site 1)	100	100	100	100	100	100	100		100				
Paradise Cut a Paradise Rd (site 2)	100	100	100	100	100	100	100		100				
Delta Mendota Canal a Byron Rd (site 3)	100	100	100	100	100	100	100		100				
Bishop Cut a Eight mile Rd (site 4)	100	100	100	100	100	100	100		100				
Cache St a Liberty Is Rd (site 5)	100	100	100	100	100	100	100		100				
Cache St off Ryer Island (site 6)	100	100	100	100	100	100	100		100				
Steamboat St off Grand Island (site 7)	100	100	100	100	100	100	100		100				
Utatis Cr a Salem Rd (site 8)	0	0	0	0	0	0	0	organophosphate=nd <sup>3</sup> carbofuran=1.0	0	partial			
Tom Paine St a MacArthur Rd (site 9)	100	100	100	100	100	100	100						
Fabian Tract main drain (site 10)	100	100	100	100	100	100	100						
Bishop Tract main drain (site 11)	100	0	0	0	0	0	0	organophosphate=nd		negligible			
Elkhorn St on Ryer Island (site 12)	100	100	100	100	100	100	100						
Sutter Island main drain (site 13)	100	100	100	100	100	100	100						
Laboratory Ctl	100	100	100	100	100	100	100		100				

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity. <sup>3</sup> Analysis by U.S. Geological Survey

Table 8. (Continued)

Date: 30 March 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained
Old R. @ Tracy Rd (Site 1)	100	100	100	100	100	100	100		
Paradise Cut @ Paradise Rd (Site 2)	100	100	100	100	100	90	90		
Delta Mendota Canal @ Byron Rd (Site 3)	100	100	100	100	100	100	100		
Bishop Cut @ Eight mile Rd (Site 4)	100	100	100	100	100	100	100		
Cache Sl @ Liberty Is Rd (Site 5)	100	100	100	100	100	100	100		
Cache Sl off Ryer Island (Site 6)	100	100	100	100	100	100	100		
Steamboat Sl off Grand Island (Site 7)	100	100	100	100	100	100	100		
Ulati's Ck @ Salem Rd (Site 8)	100	100	100	100	100	100	100		
Tom Paine Sl @ MacArthur Rd (Site 9)	100	100	100	100					
Fabian Tract main drain (Site 10)	100	100	100	100					
Bishop Tract main drain (Site 11)	100	100	100	100					
Elkhorn Sl on Ryer Island (Site 12)	100	100	100	100					
Sutter Island main drain (Site 13)	100	100	100	100					
Laboratory Ctl	90	90	90	90	90	90	90		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected.

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Table 8. (Continued)

Date: 6 April 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained <sup>2</sup>
Old R. @ Tracy Rd (Site 1)	100	100	100	100	100	100	100		
Paradise Cut @ Paradise Rd (Site 2)	100	100	100	100	100	100	100		
Delta Mendota Canal @ Byron Rd (Site 3)	100	100	100	100	100	100	100		
Bishop Cut @ Eight mile Rd (Site 4)	100	100	100	100	100	100	100		
Cache Sl @ Liberty Is Rd (Site 5)	100	100	100	100	100	100	100		
Cache Sl off Ryer Island (Site 6)	100	90	90	90	90	90	90		
Steamboat Sl off Grand Island (Site 7)	100	100	100	100	100	100	100		
Ulatis Ck @ Salem Rd (Site 8)	100	100	100	100	100	80	30	diazinon=0.24 <sup>3</sup>	complete
Tom Paine Sl @ MacArthur Rd (Site 9)	100	100	100	100					
Fabian Tract main drain (Site 10)	100	100	100	90					
Bishop Tract main drain (Site 11)	100	100	100	100					
Elkhorn Sl on Ryer Island (Site 12)	90	90	90	90					
Sutter Island main drain (Site 13)	100	100	100	100					
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> No samples sent in for carbamate analysis because of lack of funds. <sup>3</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 8. (Continued)

Date: 13 April 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1,2</sup> (ppb)	Amount of Toxicity explained <sup>3</sup>
Old R. @ Tracy Rd (Site 1)	100	100	100	100	100	100	100		
Paradise Cut @ Paradise Rd (Site 2)	100	50	0	0	0	0	0	carbamates=nd organophosphate=nd	negligible
Delta Mendota Canal @ Byron Rd (Site 3)	100	100	100	100	90	80	80		
Bishop Cut @ Eight mile Rd (Site 4)	0	0	0	0	0	0	0	carbofuran=1.9 chlorpyrifos=0.01 diazinon=0.01	partial
Cache Sl @ Liberty Is Rd (Site 5)	100	90	90	80	80	80	80		
Cache Sl off Ryer Island (Site 6)	100	100	100	100	100	90	90		
Steamboat Sl off Grand Island (Site 7)	100	100	100	100	100	100	100		
Ulatis Ck @ Salem Rd (Site 8)	90	90	90	90	90	90	90		
Tom Paine Sl @ MacArthur Rd (Site 9)	100	100	100	100					
Fabian Tract main drain (Site 10)	100	100	100	100					
Bishop Tract main drain (Site 11)	100	100	100	100				carbamates=nd organophosphate=nd	
Elkhorn Sl on Ryer Island (Site 12)	100	100	100	100					
Sutter Island main drain (Site 13)	100	100	100	100					
Laboratory Ctl	100	100	90	90	90	90	90		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> U.S. Geological Survey analysis, no samples sent to Eureka Laboratory. <sup>3</sup> Estimates are the best professional judgement of author. Complete = toxicity can be explained by pesticides measured. Partial = Pesticides detected contribute to, but do not explain all the observed toxicity. Negligible = Pesticide concentrations cannot explain observed toxicity.

Table 8. (Continued).

Date: 20 April 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of toxicity explained
Old R. @ Tracy Rd (Site 1)	100	100	90	90	90	90	90		
Paradise Cut @ Paradise Rd (Site 2)	100	100	100	70	70	70	70		
Delta Mendota Canal @ Byron Rd (Site 3)	70	70	70	70	70	70	70		
Bishop Cut @ Eight mile Rd (Site 4)	100	90 <sup>2</sup>	90	90	80	80	80		
Cache Sl @ Liberty Is Rd (Site 5)	100	90	90	90	90	90	90		
Cache Sl off Ryer Island (Site 6)	90	90	80	80	80	80	70		
Steamboat Sl off Grand Island (Site 7)	90	90	90	90	90	90	90		
Ulatis Ck @ Salem Rd (Site 8)	90	90	90	90	90	90	90		
Tom Paine Sl @ MacArthur Rd (Site 9)	100	100	100	100					
Fabian Tract main drain (Site 10)	100	100	100	100					
Bishop Tract main drain (Site 11)	100	100	100	100					
Elkhorn Sl on Ryer Island (Site 12)	80	80	80	80					
Sutter Island main drain (Site 13)	100	100	100	100					
Laboratory Ctl	100	100	100	100	100	100	100		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> One animal accidentally killed laboratory personnel.

Table 8. (Continued).

Date: 27 April 1992									
Station	Ceriodaphnia survival (%) by day							Pesticide detections <sup>1</sup> (ppb)	Amount of Toxicity explained
Old R. @ Tracy Rd (Site 1)	100	100	100	100	100	100	100		
Paradise Cut @ Paradise Rd (Site 2)	100	100	100	100	100	100	100		
Delta Mendota Canal @ Byron Rd (Site 3)	100	100	80	70	70	70	70		
Bishop Cut @ Eight mile Rd (Site 4)	100	100	100	100	100	100	100		
Cache Sl @ Liberty Is Rd (Site 5)	100	100	100	100	90	80 <sup>2</sup>	80		
Cache Sl off Ryer Island (Site 6)	100	100	100	100	100	100	100		
Steamboat Sl off Grand Island (Site 7)	100	100	100	100	100	100	100		
Ulatis Ck @ Salem Rd (Site 8)	100	100	90	90	90	90	90		
Tom Paine Sl @ MacArthur Rd (Site 9)	100	100	100	100					
Fabian Tract main drain (Site 10)	100	100	100	100					
Bishop Tract main drain (Site 11)	100	100	100	100					
Elkhorn Sl on Ryer Island (Site 12)	90	80	80	80					
Sutter Island main drain (Site 13)	100	100	100	100					
Laboratory Ctl	100	100	100	100	100	90	90		

<sup>1</sup> Blanks indicate no pesticide analysis; nd = non detected. <sup>2</sup> One animal accidentally killed by laboratory personnel.

Table 9. Summary of pesticide detections (ppb) in surface water in the orchard-alfalfa study conducted between 1 January and 27 April, 1992. See Tables 3 and 8 for specific locations and dates of each observation.

Pesticide	Mean <sup>2</sup>	criteria <sup>1</sup>			
		Performance goal <sup>3</sup>	Maxima <sup>4</sup>	1 hour <sup>5</sup>	4 day <sup>5</sup>
diazinon	1.07, 0.02 - 6.84, 26		0.009		
parathion	0.01, 0.01 - 0.01, 2			0.065	0.013
malathion	0.02, 0.01 - 0.04, 3	0.1		0.1	
chlorpyrifos	0.01, 2			0.083	0.041
carbofuran	1.45, 1.0 - 1.90, 2	0.4			
diuron	6.09, 0.1 - 30.60, 23		1.6		
bromocil	3.74, 1.32 - 7.50, 3				
methidathion	2.17, 0.14 - 15.1, 11				
propham	12.20, 3.60 - 19.9, 5				
flurmeturon	3.0, 1				
diazinon-oxon	0.43, 1				

<sup>1</sup> Recommended criteria to protect freshwater aquatic life. <sup>2</sup> Mean, range, number of detections  
<sup>3</sup> Regional Board performance goal. <sup>4</sup> National Academy of Science recommended maxima criteria.  
<sup>5</sup> EPA recommended criteria.

**APPENDIX A**  
**WATER QUALITY DATA**

Table 1. Bioassay water quality measurements for the orchard portion of the study.

Date: 13 January 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Feather R @ Lee Rd	7.8	8.0	100	145	8.2	7.7	
Sacramento R @ Meridian	7.8	8.4	171	220	8.3	7.7	
Mokelumne R @ New Hope Rd	6.9	7.7	49	90	8.3	7.6	
French Camp Sl @ Manthey Rd	7.6	8.0	500	610	6.5	7.1	11.5
Old R @ Cohen Rd	7.8	8.5	799	1000	8.1	7.3	
San Joaquin R @ Bowman Rd	7.2	7.7	800	1000	7.9	6.1	
Clark's Ditch @ White Rd	no flow						
Gilsizer Sl @ George Washington Rd	8.2	8.2	190	245	8.3	7.9	
Ledgewood Ck @ Portsmouth Ct	8.1	8.4	699	790	6.9	8.0	
Lone Tree Ck @ Austin Rd	7.9	8.2	430	550	8.3	6.7	
Marsh Ck @ Cypress Rd	no flow						
Laboratory control	8.2	8.3	220	300	8.3	7.6	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 1. (Continued).

Date: 20 January 1992							
Site	Ph		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Feather R @ Lee Rd	7.7	7.8	135	150	8.2	7.3	
Sacramento R @ Meridian	8.2	7.8	210	296	8.3	7.3	
Mokelumne R @ New Hope Rd	7.4	7.8	91	105	8.2	7.3	
French Camp Sl @ Manthey Rd	7.4	6.9	999	1000	8.2	5.9	5.3
Old R @ Cohen Rd	8.0	7.8	1000	1050	8.2	7.2	
San Joaquin R @ Bowman Rd	8.2	7.8	800	1000	8.2	6.2	
Clark's Ditch @ White Rd	no flow						
Gilsizer Sl @ George Washington Rd	8.0	7.7	319	301	7.5	7.3	
Ledgewood Ck @ Portsmouth Ct	8.2	7.4	700	750	8.2	7.4	
Lone Tree Ck @ Austin Rd	8.2	7.7	365	370	8.2	8.0	11.5
Marsh Ck @ Cypress Rd	8.3	7.9	1550	1500	8.2	7.6	
Laboratory control	8.0	7.3	230	270	7.8	7.5	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)



Table 1. (Continued).

Date: 27 January 1992							
Site	Ph		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Feather R @ Lee Rd	7.9	8.1	117	112	8.0	8.2	
Sacramento R @ Meridian	7.7	8.3	208	200	7.9	8.0	
Mokelumne R @ New Hope Rd	7.8	7.3	60	70	8.1	7.2	0.2
French Camp Sl @ Manthey Rd	7.6	8.2	900	900	7.9	7.5	13.0
Old R @ Cohen Rd	7.8	8.4	1200	1005	7.6	7.8	
San Joaquin R @ Bowman Rd	8.1	8.4	1010	1000	7.8	7.8	
Clark's Ditch @ White Rd	no flow						
Gilsizer Sl @ George Washington Rd	7.5	7.9	315	330	7.2	7.5	0.5
Ledgewood Ck @ Portsmouth Ct	8.2	8.2	800	650	8.0	8.0	
Lone Tree Ck @ Austin Rd	8.0	7.9	380	370	7.9	7.3	6.0
Marsh Ck @ Cypress Rd	8.3	8.5	1510	1350	7.9	8.1	
Laboratory control	7.8	8.3	240	250	8.0	8.0	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 1. (Continued).

Date: 3 February 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Feather R @ Lee Rd	7.6	7.6	90	130	8.2	7.6	
Sacramento R @ Meridian	7.9	7.8	98	200	8.0	7.5	
Mokelumne R @ New Hope Rd	7.3	7.3	40	70	8.1	7.9	1.0
French Camp Sl @ Manthey Rd	7.5	8.1	700		8.1	7.7	3.5
Old R @ Cohen Rd	7.6	8.0	710	1050	8.2	7.4	
San Joaquin R @ Bowman Rd	7.3	8.1	750	1020	7.9	7.5	
Clark's Ditch @ White Rd	no flow						
Gilsizer Sl @ George Washington Rd	7.1	7.6	210	275	8.1	7.2	1.5
Ledgewood Ck @ Portsmouth Ct	7.7	8.4	600	600	8.2	7.6	
Lone Tree Ck @ Austin Rd	8.1	8.1	445	599	8.2	7.0	9.0
Marsh Ck @ Cypress Rd	8.3	8.6	1250	1600	8.1	7.5	
Laboratory control	7.7	7.8	230	217	8.1	7.7	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 1. (Continued).

Date: 10 February 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Feather R @ Lee Rd	7.6	7.8	120	120	7.9	7.5	<0.1
Sacramento R @ Meridian	7.5	8.0	200	200	7.5	7.3	
Mokelumne R @ New Hope Rd	7.1	7.4	60	65	7.5	7.6	
French Camp Sl @ Manthey Rd	7.3	8.0	500	500	7.4	7.5	3.0
Old R @ Cohen Rd	7.8	8.4	1000	1080	7.8	7.3	
San Joaquin R @ Bowman Rd	7.8	8.2	1100	1100	8.1	7.3	
Clark's Ditch @ White Rd	7.4	7.3	118	123	7.7	6.1	0.4
Gilsizer Sl @ George Washington Rd	7.3	7.5	150	155	7.5	6.8	1.2
Ledgewood Ck @ Portsmouth Ct	7.9	8.2	480	460	7.9	7.9	<0.1
Lone Tree Ck @ Austin Rd	7.9	8.2	600	540	8.0	6.8	12.5
Marsh Ck @ Cypress Rd	8.1	8.5	1400	1350	7.9	6.7	
Laboratory control	7.7	8.2	240	265	8.0	7.5	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 1. (Continued).

Date: 17 February 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Feather R @ Lee Rd	7.9	7.3	100	111	8.0	7.5	
Sacramento R @ Meridian	7.9	7.5	115	129	8.1	7.6	
Mokelumne R @ New Hope Rd	7.8	7.1	70	82	8.0	7.6	
French Camp Sl @ Manthey Rd	7.8	7.3	160	170	7.8	7.4	4.0
Old R @ Cohen Rd	7.6	7.8	325	339	7.6	7.7	5.0
San Joaquin R @ Bowman Rd	7.4	7.9	500	500	7.2	7.9	4.0
Clark's Ditch @ White Rd	7.9	8.0	485	450	8.2	7.9	1.0
Gilsizer Sl @ George Washington Rd	7.2	7.7	160	190	7.8	7.9	1.0
Ledgewood Ck @ Portsmouth Ct	8.1	8.4	700	650	8.1	7.2	
Lone Tree Ck @ Austin Rd	7.4	7.6	310	320	7.0	7.0	8.0
Marsh Ck @ Cypress Rd	8.2	8.3	710	750	8.2	7.4	
Laboratory control	8.2	7.7	250	269	8.0	7.6	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 1. (Continued).

Date: 24 February 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Feather R @ Lee Rd	7.0	7.9	120	130	8.2	7.5	
Sacramento R @ Meridian	7.2	7.6	130	145	8.0	7.5	
Mokelumne R @ New Hope Rd	6.9	7.4	70	100	8.2	7.3	
French Camp Sl @ Manthey Rd	7.2	7.5	250	255	8.2	6.8	3.0
Old R @ Cohen Rd	7.7	7.9	750	750	7.8	7.1	
San Joaquin R @ Bowman Rd	7.2	8.0	700		8.2	7.2	0.5
Clark's Ditch @ White Rd	8.0	8.5	800	850	8.3	7.6	<0.1
Gilsizer Sl @ George Washington Rd	7.5	8.2	420	450	7.6	7.5	<0.1
Ledgewood Ck @ Portsmouth Ct	8.0	8.3	650	700	8.2	7.4	<0.1
Lone Tree Ck @ Austin Rd	7.3	7.7	400	480	7.8	4.3	15.0
Marsh Ck @ Cypress Rd	7.8	8.4	850	825	8.2	7.5	
Laboratory control	7.7	7.8	240	260	8.3	7.5	<0.1

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 2. Bioassay water quality measurements for the alfalfa portion of the study.

Date: 9 March 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Old R @ Tracy Rd	7.8	8.0	950	1100	8.1	7.5	
Paradise Cut @ Paradise Rd	8.4	8.2	1200	1400	8.0	7.3	0.4
Delta Mendota Canal @ Byron Rd	7.7	7.9	650	690	8.0	7.5	
Bishop Cut @ 8 mile Rd	7.8	7.8	295	360	8.1	7.4	
Cache Slough @ Liberty Island Rd	7.7	7.9	330	400	8.1	7.6	
Cache Slough @ Ryer Island	7.6	7.9	221	280	8.2	7.7	
Steamboat Slough off Grand Island	7.6	7.8	180	206	8.1	7.6	
Ulati Ck @ Salem Rd	8.4	8.3	700	820	8.1	7.5	
Fabian Tract Drain	7.3	8.3	1180	1390	8.1	7.6	
Bishop Tract Main Drain	7.9	8.4	900	1090	7.6	8.1	
Elkhorn Slough @ Ryer Island	7.7	8.4	950	1120	8.2	8.1	
Sutter Island Main Drain	7.5	8.4	900	1050	8.2	8.0	
Laboratory control	8.2	7.8	231	269	8.0	7.7	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 2. (Continued)

Date: 16 March 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Old R @ Tracy Rd	8.0	8.3	1300	1100	7.9	7.1	
Paradise Cut @ Paradise Rd	7.9	8.2	1200	1080	8.2	7.3	
Delta Mendota Canal @ Byron Rd	7.5	8.0	700	650	8.3	7.6	
Bishop Cut @ 8 mile Rd	7.6	7.9	335	340	8.1	7.6	
Cache Slough @ Liberty Island Rd	7.5	8.0	405	370	8.2	7.6	
Cache Slough @ Ryer Island	7.6	7.9	270	285	8.2	7.6	
Steamboat Slough off Grand Island	7.4	7.9	235	240	8.3	7.6	
Ulati Ck @ Salem Rd	8.1	8.2	700	600	8.1	7.9	0.3
Tom Paine Slough @ MacArthur Rd	8.0	8.6	1750	1720	8.2	7.2	
Fabian Tract Drain	7.5	8.6	1600	1580	7.5	7.5	
Bishop Tract Main Drain	7.6	8.4	1200	1150	8.1	7.9	<0.1
Elkhorn Slough @ Ryer Island	7.8	8.7	1200	1110	8.3	7.5	
Sutter Island Main Drain	7.4	8.6	900	950	8.0	7.6	
laboratory control	8.0	8.0	320	260	8.3	7.7	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 2. (Continued)

Date: 23 March 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Old R @ Tracy Rd	8.3	8.1	1300	1230	7.8	7.3	
Paradise Cut @ Paradise Rd	8.4	8.0	1410	1390	7.9	7.3	
Delta Mendota Canal @ Byron Rd	8.1	7.8	499	490	8.1	7.6	
Bishop Cut @ 8 mile Rd	8.2	7.8	341	310	8.1	7.3	
Cache Slough @ Liberty Island Rd	8.2	8.0	400	400	8.2	7.7	
Cache Slough @ Ryer Island	8.0	7.9	251	230	8.1	7.8	
Steamboat Slough off Grand Island	8.0	7.8	200	200	7.9	7.6	
Ulatis Ck @ Salem Rd	8.3	8.0	450	420	8.1	7.7	1.0
Tom Paine Slough @ MacArthur Rd	8.3	8.6	1599	1499	8.0	7.9	
Fabian Tract Drain	7.7	8.4	1200	1150	7.2	8.2	
Bishop Tract Main Drain	8.1	8.6	1190	1090	7.6	7.6	<0.1
Elkhorn Slough @ Ryer Island	8.3	8.6	1250	1150	7.9	8.0	
Sutter Island Main Drain	7.9	8.2	300	285	8.0	8.1	
Laboratory control	8.4	7.8	249	280	8.0	7.7	

<sup>1</sup> Electrical conductivity ( $\mu\text{mhos/cm}$ ). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)



Table 2. (Continued)

Date: 30 March 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Old R @ Tracy Rd	8.1	8.4	1100	1050	7.9	7.9	
Paradise Cut @ Paradise Rd	8.2	8.4	1100	1000	7.8	7.9	
Delta Mendota Canal @ Byron Rd	8.0	8.2	420	410	7.9	7.9	
Bishop Cut @ 8 mile Rd	8.1	8.2	320	320	7.9	7.9	
Cache Slough @ Liberty Island Rd	8.1	8.3	340	340	8.0	7.8	
Cache Slough @ Ryer Island	7.9	8.2	260	270	8.1	7.9	
Steamboat Slough off Grand Island	7.9	8.2	235	245	8.0	7.9	
Ulati Ck @ Salem Rd	7.9	7.6	1100	1050	8.3	8.4	
Tom Paine Slough @ MacArthur Rd	8.4	8.6	1600	1500	8.1	7.8	
Fabian Tract Drain	7.9	8.2	1550	1400	7.5	6.5	
Bishop Tract Main Drain	7.8	8.7	1100	1050	7.9	8.1	
Elkhorn Slough @ Ryer Island	8.3	8.7	1200	1100	7.9	8.1	
Sutter Island Main Drain	8.2	8.8	950	890	8.1	8.4	
Laboratory control	7.6	8.2	260	260	8.1	7.8	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 2. (Continued)

Date: 6 April 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Old R @ Tracy Rd	7.9	8.3	800	1010	8.0	8.1	
Paradise Cut @ Paradise Rd	7.5	8.3	710	910	8.2	8.2	
Delta Mendota Canal @ Byron Rd	7.5	8.1	260	341	7.7	8.3	
Bishop Cut @ 8 mile Rd	7.8	8.1	210	280	7.8	8.3	
Cache Slough @ Liberty Island Rd	7.7	8.3	270	359	8.0	8.3	
Cache Slough @ Ryer Island	7.5	8.2	200	270	8.2	8.4	
Steamboat Slough off Grand Island	7.4	8.1	160	230	8.1	8.2	
Ulati Ck @ Salem Rd	8.6	8.7	800	1010	7.9	8.0	1.0
Tom Paine Slough @ MacArthur Rd	8.2	8.2	900	1200	7.9	7.7	
Fabian Tract Drain	6.9	8.1	905	1210	7.9	7.7	
Bishop Tract Main Drain	7.6	8.4	899	1150	7.9	7.8	
Elkhorn Slough @ Ryer Island	7.9	8.4	590	790	8.2	7.9	
Sutter Island Main Drain	7.5	8.4	510	700	8.2	8.0	
Laboratory control	7.7	8.1	231	241	8.2	8.5	

<sup>1</sup> Electrical conductivity ( $\mu\text{mhos/cm}$ ). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 2. (Continued)

Date: 13 April 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Old R @ Tracy Rd	8.0	8.3	1000	950	7.9	7.9	0.1
Paradise Cut @ Paradise Rd	8.1	8.3	925	900	8.1	7.4	0.1
Delta Mendota Canal @ Byron Rd	7.8	8.3	800	800	8.2	8.1	
Bishop Cut @ 8 mile Rd	7.6	8.2	425	442	6.7	7.4	<0.1
Cache Slough @ Liberty Island Rd	8.0	8.3	345	360	8.3	8.0	
Cache Slough @ Ryer Island	8.0	8.1	260	265	8.3	8.0	
Steamboat Slough off Grand Island	7.9	8.2	220	230	8.0	8.0	
Ulati Ck @ Salem Rd	8.4	8.5	800	800	8.2	7.8	
Tom Paine Slough @ MacArthur Rd	8.0	8.3	1000	1010	8.3	7.8	
Fabian Tract Drain	7.3	8.1	1200	1200	6.2	6.6	
Bishop Tract Main Drain	7.9	8.1	275	288	7.9	7.8	
Elkhorn Slough @ Ryer Island	7.6	8.5	550	520	7.6	7.9	
Sutter Island Main Drain	8.0	8.4	900	900	8.3	8.0	
Laboratory control	7.9	8.0	230	250	8.0	8.1	

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 2. (Continued)

Date: 20 April 1992							
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>
	start	end	start	end	start	end	
Old R @ Tracy Rd	8.2		1021		7.9		
Paradise Cut @ Paradise Rd	8.2		1134		8.1		<0.2
Delta Mendota Canal @ Byron Rd	7.9		596		8.2		<0.2
Bishop Cut @ 8 mile Rd	8.7		287		6.7		
Cache Slough @ Liberty Island Rd	8.2		368		8.3		
Cache Slough @ Ryer Island	8.2		257		8.3		<0.2
Steamboat Slough off Grand Island	8.6		202		8.0		
Ulati Ck @ Salem Rd	8.6		696		8.2		
Tom Paine Slough @ MacArthur Rd	8.1		1031		8.3		
Fabian Tract Drain	7.7		1480		8.2		
Bishop Tract Main Drain	7.7		1183		8.0		
Elkhorn Slough @ Ryer Island	8.1		386		8.1		
Sutter Island Main Drain	8.3		689		8.1		
Laboratory control	8.2		196		8.0		

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

Table 2. (Continued)

Date: 27 April 1992								
Site	pH		EC <sup>1</sup>		DO <sup>2</sup>		NH <sub>3</sub> -N <sup>3</sup>	Dilution (%)
	start	end	start	end	start	end		
Old R @ Tracy Rd	7.7		1000		8.0			
Paradise Cut @ Paradise Rd	7.7		1000		7.2			
Delta Mendota Canal @ Byron Rd	7.8		340		8.1			
Bishop Cut @ 8 mile Rd	7.8		262		8.2			
Cache Slough @ Liberty Island Rd	7.9		310		8.1			
Cache Slough @ Ryer Island	7.8		224		8.1			
Steamboat Slough off Grand Island	8.0		170		7.9			
Ulati Ck @ Salem Rd	7.8		640		7.6			
Tom Paine Slough @ MacArthur Rd	7.5		1000		7.8			
Fabian Tract Drain	7.4		1100		7.9			
Bishop Tract Main Drain	7.7		620		8.1			
Elkhorn Slough @ Ryer Island	7.8		250		7.9			
Sutter Island Main Drain	7.9		330		8.0			
Laboratory control	8.1		230		7.8			

<sup>1</sup> Electrical conductivity ( $\mu$ mhos/cm). <sup>2</sup> Dissolved oxygen (mg/l). <sup>3</sup> Ammonia (mg/l)

**APPENDIX B**

**ORCHARD SAMPLING LOCATIONS**

Table 1. Description of site locations employed in the Regional Board's 1992 Orchard Study. All samples were collected from bridges or by wading out into the waterbody.

Site No.	Description
1.	Feather River. Sample collected from east bank about 200 yards downstream from the intersection of Lee Rd and the Garden Highway.
2.	Sacramento River. Sample collected from the east bank about 200 yards north of the Highway 20 Meridian Bridge.
3.	Mokelumne River. Sample collected from the middle of the New Hope Rd Bridge. All samples collected within one hour of lower low tide. The site is located within the statutory boundary of the Delta.
4.	French Camp Slough. Sample collected from the middle of Manthey Rd Bridge. All samples collected within one hour of low tide. The site is located at the statutory boundary of the Delta. French Camp Slough discharges into the San Joaquin River south of the City of Stockton.
5.	Old River. Sample collected from the south bank of the River off Cohen Road where the road first leaves the levee. All samples collected within one hour of low tide. Site is within the statutory boundary of the Delta.
6.	San Joaquin River. Sample collected from the east bank of the San Joaquin River at Bowman Road. All samples collected within one hour of low tide. Site is within the statutory boundary of the Delta.
7.	Clark's Ditch. Sample collected by driving north about 1 mile on dirt road at the intersection of White and John School Road. Clark's Ditch carries water from Petroleum and several unnamed Creeks to Colusa Basin Drain.
8.	Gilsizer Slough. Sample collected from south bank of Slough at South George Washington Rd. The Slough discharges into Butte Slough via the Bannon Pumping Plant.
9.	Ledgewood Creek. Sample collected from northeast bank of Creek off Portsmouth Court in the City of Fairfield. The site is located within the San Francisco Bay Regional Water Quality Control Board's (Region 2) jurisdiction. The Creek discharges into Peytonia Slough in Suisun Marsh.
10.	Lone Tree Creek. Sample collected from under bridge at Austin Road. The Creek discharges into French Camp Slough.
11.	Marsh Creek. Sample collected on the east bank just upstream of the Cypress Road Bridge. The Creek discharges into the western Delta at Big Break.

**APPENDIX C**

**PESTICIDE SOURCES AND POTENTIAL MECHANISMS OF DORMANT  
SPRAY OFF-TARGET MOVEMENT**



## Sources

Dormant sprays are applied in the winter to deciduous orchards in California to control a number of pests including scales and boring insects (Chemical and Pharmaceutical Press, 1990). Slightly more than one million pounds of five dormant sprays were applied in 1991 (Table 6, main report). Two lines of evidence suggest that most of the diazinon and methidathion detected in this study are from orchards. First, toxicity to Ceriodaphnia from both insecticides was detected in water draining from all six small watersheds monitored (Table 3 of main report). These basins were selected as more than 10 percent of their acreage is planted in orchards (Table 1 of main report). Two west Stanislaus County watersheds without orchards were monitored in the winter of 1991 and 1992 as part of the other San Joaquin pesticide study (Foe, in prep). Insufficient funds prevented routine pesticide analysis; however, no toxicity was ever detected in their runoff.

The second line of evidence suggesting that diazinon and methidathion primarily originate from orchards is that both chemicals are used mostly on orchards during the winter (about 70 percent of total use, Tables 1 and 2). Other major uses of methidathion in the winter are on alfalfa and walnuts (Table 1 and Table 6, main report). Use on alfalfa is not likely to have contributed to the present problem as methidathion is first applied on alfalfa about a month after it was last observed in this study. In contrast, about four thousand pounds of methidathion was applied in January and February, 1990, on walnuts. Walnuts are the second most common type of deciduous orchard grown in the Valley (Table 7, main report) and were present at varying densities in all the watersheds monitored (Table 1, main report). Walnuts may be a source of some of the methidathion measured in this study. Possible off-target movement of methidathion from walnuts merits further evaluation.

Other major uses of diazinon (Table 2) are on alfalfa, landscape maintenance and structural pest control. Like methidathion, use of diazinon on alfalfa occurs later and so can be discounted. About 60,000 pounds of diazinon was used in the State during the first quarter on landscape maintenance and structural pest control. Most of this application probably occurred in urban areas. Diazinon runoff from urban areas could enter surface water through discharges from either publicly owned sewage treatment plants or from city storm drains. Nationally, diazinon is recognized from TIE work as a major cause of Ceriodaphnia toxicity in sewage treatment plant effluent (Mount et al., 1992). Sewage treatment plants are unlikely to have contributed much to the present problem as their flow is an insignificant portion of the volume of surface water in the Central Valley. Less information exists on organophosphate pesticide concentrations in storm drain runoff. To our knowledge, only three studies have monitored for diazinon in urban runoff. The City of Sacramento analyzed 33 urban runoff samples for organophosphate pesticides (detection limit was 1.0 ppb) during 1991-92. Diazinon was measured in three samples at concentrations between 1.0 and 2.4 ppb (personal communication, Eva Butler). The samples were collected in sumps from residential and residential/light commercial type use areas. There are few orchards around the City of Sacramento. Therefore, the source of the diazinon was likely from non-orchard applications within the City. Second, the U.S. Geological Survey conducted a water quality and stream flow study of runoff from Santa Clara Valley in 1979-81 (Sylvester, 1986). The water monitored in this

study originated principally as runoff from undeveloped areas, orchards and urban sites. Diazinon was measured in 16 of 24 samples at concentrations between 0.01 and 0.34 ppb (mean=0.06 ppb). Nine of these samples were collected in urban areas. The source of the diazinon may be either from use within residential areas or from deciduous orchards in the surrounding watershed. Finally, the U.S. Geological Survey conducted an extensive evaluation of urban runoff in the City of Fresno between 1981 and 1983 (Oltmann and Shulters, 1987; Oltmann et al., 1987). Eighty-five urban runoff samples were analyzed for organophosphate pesticides (detection limit of 0.01 ppb). Diazinon, malathion, and parathion were the most common insecticides detected. Diazinon was observed in all samples at a mean concentration of 0.88 ppb (range: 0.06-18.0 ppb). The Survey also measured pesticide concentrations in composite rain samples from 21 storms. The same three chemicals were commonly observed. Diazinon was detected in all 54 composite rainfall samples at a mean concentration of 0.14 ppb (range: 0.01-0.93 ppb). The Survey concluded that the principal source of the insecticides in rain was from applications on orchards. The study also concluded that pesticide concentrations in Fresno urban runoff was likely from wet and dry weather deposition from orchards and from residential use within the City. In conclusion, three studies demonstrate that diazinon may be present in urban runoff. However, in two of these it is not clear whether the primary source of the diazinon is from use within Cities or from applications on surrounding orchards. Studies need to be undertaken to better ascertain both the concentration and sources of diazinon in urban runoff.

#### Mechanisms responsible for off-target pesticide movement

To date, no work has been done to establish how dormant sprays get into surface water. Data collected in this study indicate that contamination is occurring during both wet and dry weather. At least three transfer mechanisms appear possible--drift during application, direct runoff from orchards, and contamination through residues carried in fog and rain. The most common method of applying dormant sprays is with a tractor towed air blast speed sprayer. The rig is traditionally pulled down each row enveloping the trees on either side with a fine mist of sticker oil and insecticide. The application relies on blower induced air turbulence to evenly disperse the insecticide. Studies have been conducted on off-target movement of sprays during aerial application (Ernst, et al., 1991), however, to our knowledge no similar work has been done on ground applications. Drift induced contamination may be most important in situations such as at Gilsizer Slough where there is no buffer strip between the orchard and the Slough.

Results from this study suggest that the greatest loading of pesticides to the Delta appears to occur during rainstorms. It is likely that some pesticide residue may originate directly from orchard runoff. Runoff from orchards may become contaminated with pesticides either through direct contact of rain water with insecticides on tree surfaces or the orchard floor. Standing water in orchards in winter and early spring can promote root and crown rot diseases (Phytophthora spp.) and may stress trees by depriving their roots of oxygen (University of California, 1981 and 1987). Therefore, many Central Valley orchards are probably managed to drain off the excess rain water. This practice could contribute to off-site movement of orchard pesticide residues during rainy weather.

Finally, several studies have measured dormant sprays in fog and rain water in the San Joaquin Valley during the winter. Concentrations of the four principal dormant sprays and their oxon degradation products have been detected in fog at concentrations up to 60 and 75 ppb, respectively (Glotfelty *et al.*, 1987, 1990). Organophosphate pesticide concentrations in rainwater appear to average about two and a half orders of magnitude lower than in fog (Glotfelty *et al.*, 1987; Oltmann and Shulters, 1987). The chemicals are thought to enter atmospheric moisture from drift during orchard spraying operations, by wind erosion of soil or formulation particles, and by post application volatilization (Taylor and Glotfelty, 1988). The City of Fresno is surrounded by deciduous orchards. As previously mentioned, the average concentration of diazinon in composite rain water samples from 21 storms in the Fresno area was 0.14 ppb (Oltmann and Shulters, 1987). The two highest mean diazinon composite values were 0.43 and 0.68 ppb for 0.53 and 0.34 inch storm events, respectively. If water samples from these storms had been tested in bioassays, they probably would have been found to be acutely toxic to *Ceriodaphnia* as the 24 hour diazinon LC<sub>50</sub> concentration for the water flea is between 0.4 and 0.6 ppb (Table 5, main report).

Deposition of pesticides from atmospheric contamination has been found to decrease with distance from the place of application (Zabik *et al.*, 1992). Therefore, the pesticide rainfall values reported for the City of Fresno may be among the highest concentrations likely to occur in the Valley. However, Zabik *et al.* measured organophosphate pesticides in both wet and dry deposition 50 miles from orchards at 5,000 feet in the Sierra Nevada mountains. These results suggest that runoff from non-orchard areas in both the Valley and surrounding mountains may be contaminated to varying degrees with dormant sprays and their degradation products.

Studies are needed to quantify the relative importance of all of the above mechanisms of transporting dormant sprays and their degradation products to surface water. Results of these studies are essential in prioritizing the development of best management programs to reduce off-site contamination.

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Table 1. Statewide application of methidathion (pounds of active ingredients) in the first quarter of 1990. Data from Department of Pesticide Regulation (1990a).

Commodity	Number of applications	pounds applied
alfalfa	270	10,351
almonds	809	44,130
almonds	6	199
apples	63	5,585
apricots	47	1,462
artichokes	11	839
cherries	32	631
kiwi	49	1,298
nectarines	186	3,711
n-outdr grown cut flwrs	22	47
n-outdr container	2	70
olives	1	3
peaches	437	11,163
pears	22	433
plums	291	11,627
plums	1	1
prunes	233	15,510
structural pest control	2	17
walnuts	84	3,864
chemical total	2,568	110,947

Table 2. Statewide application of diazinon (pounds active ingredients) in the first quarter of 1990. Data from the Department of Pesticide Regulation (1990a).

commodity	number of applications	pounds applied
alfalfa	864	24,158
almonds	2029	189,418
apples	250	7,555
apricots	303	6,617
beans	11	36
beets	9	9
berries	9	73
broccoli	107	1,178
brussels sprouts	2	5
cabbage	336	592
carrots	33	688
cauliflower	67	445
celery	14	69
cherries	142	3,792
collard	8	6
landscape maintenance	790	10,829
corn	11	20
cotton	3	319
cucumber	6	25
endive	43	208
forage, hay and silage	3	55
grapes	27	570
kale	18	30
leeks	2	2
lettuce (head)	426	6,977
lettuce (leaf)	300	975
melons	67	2,660
mushrooms	58	148
mushrooms	4	167
nectarines	207	3,234
n-grns grwn	307	323
n-outdr containers or trnsplnt	354	1519
nuts, other	3	71
onions	53	2,331
oranges	7	27
oriental vegetables	13	12
parsley	1	12
peaches	515	10,107
pears	64	592
peas	49	119
pecans	2	2

Table 2. (Continued).

Commodity	number of applications	pounds applied
peppers (bell)	19	342
plums	392	7,867
potatoes	1	42
prunes	506	28,372
public health	14	14
radishes	18	298
regulatory pest control	28	44
rights of way	11	27
spinach	73	636
squash	5	198
strawberries	82	451
structural control	1	1
structural pest control	4,535	50,559
sugarbeets	6	197
sweet potatoes	2	303
swiss chard	16	16
tomatoes	136	4,049
turnips	5	40
vegetable seeds	3	2
vertebrate pest control	2	32
walnut	9	379
watermelons	4	83
chemical total	13,426	370,803

**APPENDIX D**  
**ALFALFA SAMPLING LOCATIONS**



Table 1. Description of site locations employed in the Regional Board's 1992 alfalfa study. All samples were collected from bridges or by wading out into the waterbody. Sites within the tidal prism were collected within an hour of low tide.

Site No.	Description
1.	Old River @ Tracy Road. Sample collected from the middle of the Tracy Blvd Bridge. The site is located within the statutory boundary of the Delta.
2.	Paradise Cut. Sample collected from the southern bank of Cut about 300 yards upstream from the pumphouse directly north of the intersection of MacArthur Drive and Delta Ave when the pump was running and about 800 yards downstream from the pumphouse when the pump was not running.
3.	Delta Mendota Canal. Sample collected from the southern side of the Byron HWY Bridge over the Delta Mendota Canal. Site is located within the statutory boundary of the Delta.
4.	Bishop Cut. Sample collected from the middle of the Eight Mile Road Bridge over the Cut. Site is located within the statutory boundary of the Delta.
5.	Cache Slough @ Liberty Island Road. Sample collected from the western bank of the Slough at the end of Liberty Island Road. Site is located within the statutory boundary of the Delta.
6.	Cache Slough @ Ryer Island Road. Sample collected from the eastern bank of the Slough several hundred yards north of the Elkhorn Slough pump house. Site is located within the statutory boundary of the Delta.
7.	Steamboat Slough. If main drain on Grand Island was not pumping then sample was collected downstream from pumphouse off Grand Island Road. If pump was running, then sample was collected about 250 yards upstream.
8.	Ulati Creek. Sample collected from the middle of the bridge on Brown Road near the intersection of Salem and Brown Roads.
9.	Tom Paine Slough. Sample collected about 1000 yds upstream from MacArthur Drive Bridge. Site is located within the statutory boundary of the Delta.
10.	Fabian Tract Drain. Sample collected from the second drain discharging to Fabian and Bell Canal after accessing Grimes Road from Tracy Blvd. Site is located within the statutory boundary of the Delta.
11.	Bishop Tract Main Drain. Sample collected from the Bishop Tract Main Drain at the pumphouse which discharges to Bishop Cut. Site is located within the statutory boundary of the Delta.

12. Elkhorn Slough @ Ryer Island. Sample collected from Slough at pumphouse which discharges to Cache Slough. Site is located within the statutory boundary of the Delta.

13. Sutter Island Main Drain. Sample collected from drain at pump house. Pump discharges into Elk Slough. Site is located within the statutory boundary of the Delta.